Juvenile Anadromous Fish Passage at Howard Hanson Dam and Reservoir, Green River, Washington, 1992

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ABSTRACT

We evaluated passage of juvenile anadromous fish at Howard Hanson Dam and Reservoir during the annual reservoir refill-and-evacuation cycle in 1992, and compared our findings to a similar evaluation in 1991. In 1992, as in our 1991 study, we monitored passage of juvenile chinook salmon, coho salmon, and steelhead through the dam in relation to reservoir elevation, outflow, and exit flow temperature. We monitored sooner (mid-February) in 1992 than in 1991 (mid-April) to assess possible chinook displacement from release sites. Refill also occurred sooner in 1992 (late March) than in 1991 (late May) due to low snowpack. We fished fyke traps on principal reservoir tributaries to gauge fish movement into the reservoir, and operated hydroacoustic sensors in the dam's exits to estimate total fish movement through the dam. A scoop trap was periodically fished below the dam to identify species composition of emigrants. Overall, movement of anadromous salmonids past the dam in 1992 was characterized by 1) a pulse of fish during the spring months comprised mainly of chinook subyearlings with a moderate number of coho and chinook yearlings, 2) pulses of chinook and coho yearlings in early summer with pulses of chinook subyearlings occurring throughout the summer, and 3) a large pulse of both chinook and coho subyearlings in October and November. In 1992, we estimated passage at the dam to be approximately 1,645 yearling chinook, 178,996 subyearling chinook, 7,489 yearling coho, 31,632 subyearling coho, and 32 steelhead smolts. Spring refill of the reservoir (early April) probably stopped most coho yearling emigration just as it was starting. Over 70% of the observed subyearling chinook passage at the dam occurred after spring refill (May to late November), and 97% of the observed subyearling coho passage at the dam occurred at final reservoir drawdown (late September to late November). Reduced chinook subyearling emigration during April and the latter portion of the fall drawdown period was significantly related to reservoir outflow. During the final reservoir drawdown in November, outflow accounted for approximately 37% of the variation in coho subyearling passage. Fall emigrants from the project (subyearling coho and chinook) reached the size of yearling smolts, but exhibited relatively low ATPase (smolt readiness). Key comparisons to our 1991 findings were 1) prior to spring refill, fish displaced from release sites passed the project relatively quickly in both years, 2) peak natural emigration of chinook from the tributaries into the reservoir occurred in late spring to early summer in both years, 3) spring refill may have caused substantial delay and entrapment of juvenile salmon, resulting in major late-fall emigrations of fish with low migratory readiness in both years, 4) overall survival of subyearling chinook to the dam was much greater in 1992 although overall survival in passing the dam was much lower, 5) the number of steelhead smolts passing the dam was insignificant in both years, and 6) relations between fish passage and operational variables (exit flow and exit depth) were less obvious in 1992.

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INTRODUCTION

The U.S. Army Corps of Engineers and the City of Tacoma have begun feasibility studies of the City's proposal to increase usable storage at Howard Hanson Dam from 24,155 to 58,278 acre-feet for purposes of municipal water supply and low-flow augmentation for fish. This added water storage would elevate reservoir pool levels in the spring and summer to a maximum of 1177 feet above mean sea level, as opposed to the existing maximum pool level of 1141 feet, and inundate approximately 1.3 additional miles of Green River mainstem (for a total of approximately 5.1 miles of mainstem inundated versus 3.8 miles currently). The minimum flood-control pool elevation during winter would remain at approximately 1070 feet, maintaining a one-mile-long impoundment.

During spring refill, outflow is shifted from the main outlets (two 12-foot-wide radial gates at elevation 1035 feet) to a 48-inch bypass outlet (at elevation 1069 feet) as the reservoir is raised to maximum pool elevation of 1141 feet (the reservoir may also be surcharged to elevation 1145 feet for one to two weeks after full pool is achieved for debris-removal purposes, as occurred in 1991, or surcharged to elevation 1146 for fishery flows, as occurred in 1992). The pool is then gradually drafted through the summer and fall to augment downstream flows. Flow is diverted to the smaller bypass outlet during the refill-and-drawdown period because smaller flows can be passed more effectively through this exit than through the larger radial gates.

Timing of refill varies from year to year depending on forecasted runoff. For example, in 1991 spring refill occurred relatively late (from late May to early June), but in 1992 spring refill occurred relatively early (from late March to early April) due to low snowpack in the Green River basin.

No fish passage facility was provided in Howard Hanson Dam because anadromous fish were already barred from the upper Green River watershed by the City of Tacoma's diversion dam 3.5 river miles downstream. To reclaim anadromous fish production in the upper Green River watershed, the Washington Departments of Fisheries and Wildlife, Muckleshoot Indian Tribe, and Trout Unlimited have released Green River steelhead, coho salmon, and fall chinook salmon in the watershed above Howard Hanson Dam. Annual releases of steelhead fry began in 1982, coho salmon fry in 1983, and chinook salmon fry in 1987, while adult steelhead releases began in 1992 (recent juvenile fish releases are shown in Appendix A).

Spring reservoir filling at Howard Hanson Dam poses a major threat to successful emigration of anadromous salmonids outplanted in the upper watershed. A fish passage study conducted by the Washington Department of Fisheries (WDF) in 1984 (Seiler and Neuhauser 1985) suggested that, as depth over the bypass exit increased during the spring refill, emigrating anadromous salmonids were less able to find and enter the bypass exit, and were delayed for an unknown period.

In 1991, as part of feasibility studies of added storage in Howard Hanson Reservoir, the U.S. Fish and Wildlife Service conducted a study (Dilley and Wunderlich 1992) to obtain further information on anadromous fish passage in relation to reservoir elevation and outflow, and to help define baseline passage conditions. Results suggested that, while yearling chinook and coho mostly exited the reservoir during the spring when elevations were low, subyearling chinook migrants did not enter the reservoir until late spring when full pool had already been achieved, and were delayed and entrapped in the reservoir until late summer. Subyearling coho were also believed delayed in the reservoir. To confirm these observations, we conducted a repeat study in 1992. This study (like the 1991 study) was accomplished with Corps of Engineers and project sponsor funding. Specific study objectives in 1992 were:

1) Monitor juvenile anadromous fish emigration through the dam from late winter through fall drawdown.

2) Examine juvenile anadromous fish passage through the dam in relation to reservoir elevation and outflow.

3) Compare these findings with findings from the 1991 study.

METHODS

Overview

Fish passage through the Howard Hanson project was monitored with a combination of hydroacoustic detection at the dam's exits and trapping above and below the project. Fish passage through the dam's exits was monitored hydroacoustically from February 18 to November 30, 1992. Monitoring began earlier in 1992 (mid February) than 1991 (mid April) to observe possible displacement of chinook fry which were outplanted in the upper river (above the project) in mid February.

A scoop trap was fished below the dam during this same period to assess composition of the outmigrant population. That is, because the hydroacoustic equipment did not discriminate between species or year classes of migrating juvenile anadromous fish, scoop trap catches were used as a basis for this apportionment. Estimated fish passage was then compared to exit depth, exit outflow, and outflow temperature. Fish captured in the scoop trap were examined for physical condition and length.

Fyke traps were fished in the two major reservoir tributaries: the North Fork and the Green River mainstem. Fyke trap catches were used to assess general movement trends into the reservoir for contrast with hydroacoustically estimated trends of passage past the dam. Figure 1 shows general location of the project and locations of the several traps.

Hydroacoustic Monitoring

Hydroacoustic Equipment and Operation

We employed the same continual remote, computer-based hydroacoustic monitoring system used at Howard Hanson Dam in 1991, except two elliptical beam transducers (6X12-degree) replaced two 15-degree transducers previously used to monitor the radial gates. The system consisted of three, 420-kHz transducers (two 6X12-degree and one 6-degree), three transducer rotators, an echo sounder/transceiver, a computer-based echo signal processor (ESP) and associated software programming, multiplexer/equalizer, dedicated phone line, remote control data acquisition system, and a thermal chart recorder.

When triggered by the echo sounder, the transducer emitted short sound pulses toward the area of interest. As these sound pulses encountered fish or other targets, echoes were reflected back to the transducer which then reconverted the sound energy to an electrical signal. These returning signals were amplified by the echo sounder and equalized. A target's range from the transducer was determined by the timing of its echo relative to the transmitted pulse (Raemhild, undated).

The echo sounder relayed the returning signals to the ESP and the thermal chart recorder. Returning signals passed to the ESP were recorded to hourly computer files. Returning signals passed to the thermal chart recorder could be used to produce an echogram which provided a permanent visual record of all targets detected. The echograms were initially used for setting fish tracking and processing parameters for the ESP. Once these parameters were established, the thermal chart recorder was used for periodically verifying the fish tracking and processing parameters and as a backup for the ESP in the event of a system problem.

The multiplexer/equalizer permitted the echo sounder to individually interrogate single or multiple transducers in an operator-specified sequence. This allowed transmitted pulses to be channeled from the echo sounder to the appropriate transducer, and also equalized the returning signals to compensate for differing receiving channel sensitivities.

Transducer Placement and Calibration

The intake structure at Howard Hanson Dam has three possible fish exits. Two, 12-foot-wide, side-by-side radial gates at an elevation of 1035 feet and one 48-inch-wide bypass located at 1069 feet (Figure 2). To achieve the best possible transducer position for fish passage monitoring at these intakes, two main criteria were considered: 1) maximize the available sample area, and 2) minimize hydroacoustic turbulence.

Three transducers were installed on the inside of the intake tower's trash rack to monitor fish passage. Installation was accomplished by lowering personnel in a work basket suspended from a crane after the reservoir level was dropped below an elevation of 1069 feet. Because the transducers would be underwater and inaccessible for the entire study, it was important to have the ability to move the transducers remotely. For this reason, all three transducers were installed with rotators that were controllable from the gate house at the top of the intake tower.

We monitored fish passage through the radial gates with two 6X12-degree elliptical transducers mounted on single-axis rotators at an elevation of approximately 1070 feet (Figure 2). Each transducer was located approximately on the center line of each gate, and was aligned such that the 12-degree aspect of the transducer was on the vertical axis and the 6-degree aspect was on the horizontal axis. We used elliptical transducers (instead of 15-degree transducers which were used in 1991) to decrease noise from side walls on each side of the radial gates. This change in transducers provided comparable data to 1991, but lessened data-processing time because of reduced noise.

We monitored fish passage through the bypass gate using a 6-degree transducer mounted on a dual-axis rotator directly opposite the bypass (Figure 2).

The hydroacoustic system was calibrated prior to data collection to assure that sensitivity for each receiving channel was properly equalized. In addition, calibration information was used to set the equipment so that only targets greater than -50 dB would be recorded. This target strength was chosen so that even the smallest migrants would have a high probability of returning an echo with an amplitude large enough to be recorded. Debris, which has a substantially larger target strength than fish, was eliminated by a maximum threshold.

Hydroacoustic Data Processing

All individual echo information collected by the ESP system was stored to hourly computer files. These hourly files were compressed and remotely transferred daily by phone from the dam to our home-based computer.

Computer files were processed for potentially valid fish targets based on the following parameters:

- A maximum ping gap of 10, where the "ping gap" is the number of consecutive pings (acoustic hits on a tracked fish) that can be missed from an individual tracked fish without discounting that fish as having passed through an exit. A "tracked fish" is considered to be a fish passing through a dam exit.

- A tracking window of 1 meter, where a "tracking window" is the area centered around the range from the transducer where the next echo is expected to occur, based on the slope of the vector which has been formed from the same target's previous echo.

- An average slope, or the trajectory of a tracked fish as it passes through the hydroacoustic beam, of ≥ 0.0100 and ≤ 0.100.

- A minimum target redundancy, or consecutive hits on a tracked fish, of 4 successive echoes.

- Valid fish targets used for estimates of fish passage were selected from these files based on a midpoint no closer to the transducer than 2 meters, a 75-echo maximum number of hits, and a linearity factor (the measurement of how closely the fish follows a straight-line trajectory through the hydroacoustic beam) of no less than 0.9.

Since not all of the area in front of each radial gate was covered by the transducer beam, not all fish passing through the radial gates were detected. To account for this undersampling, each detection was extrapolated across the width of the radial gate. Fish detection was weighted by the ratio of the radial gate width to the width of the acoustic beam at range. No expansion was used for the bypass exit because the transducer beam covered the entire intake at range.

When the ESP system was not working (on February 21st and 22nd), thermal chart recorder echograms were used as a substitute. Fish targets were acquired from the echograms by digitizing the information by hand and processing the files using the same criteria and expansions as mentioned above.

When neither ESP nor echogram data were available, the next-closest 24-hour data set on either side of the missing period was averaged to estimate fish passage. Periods of missing data constituted a negligible portion of all monitoring in 1992, and occurred only during portions of March 6th and 16th, October 7th and 8th, and November 15th, 22nd, and 23rd. Periods of missing data occurred due to interruptions in power supply, computer disc overloads, or changes in gate operation without notice.

Fish Trapping

Scoop Trap

All recovery of emigrants below the dam occurred at the scoop trap. The scoop trap was essentially an inclined-plane trap of WDF design. It consisted of two 38-foot-long pontoons spaced about 8 feet apart supporting an inclined screen section 6 feet wide by 6 feet deep at the mouth and 18 feet long (Figure 3). In operation, downstream migrants were swept up the inclined screen by the current and deposited in the live box. Flow into the trap was regulated by positioning the trap in the current (side to side and fore and aft) with the main winch cables anchored to shore on each bank, and by adjusting the level and angle of the inclined screen using its four winches (Figure 3).

The scoop trap was fished in the same manner and location below Howard Hanson Dam as in 1991. The scoop trap was installed about 100 yards below the dam's outlet during the second week of February. Routine trap operation began February 18th. We trapped two days each week thereafter until the first week in July. We then reduced sampling to once per week until the first week in October when we resumed sampling twice per week until the end of the study on November 30th. This pattern of fishing followed the expected abundance and diversity of migrants through the seasons: relatively high in spring and fall, but relatively low in summer.

Trap position was checked every time the trap was fished to help ensure direct alignment into the main current and optimal velocity at the trap mouth. The scoop trap position was adjusted several times throughout the study to maximize efficiency under the wide range of flow conditions from mid February though November. Entrance velocity was measured with a current meter (Swoffer model 2100) extended into the center of the trap mouth. Figure 4 shows entrance velocities obtained during the study. The optimal water velocity at the trap mouth is approximately 6 to 8 feet per second for chinook, coho, and steelhead smolts (Dave Seiler, WDF, personal communication). This optimal velocity provides maximum trapping efficiency for smolts without excessive turbulence in the live box which, at high flows, can lead to fish injury as well as mechanical damage to the trap. Lower velocities may allow fish to evade the trap.

Daily scoop trap operation occurred over a 24-hour period beginning about 0900 each trap-day. Trap checks occurred in late afternoon, midnight, and the following morning to reduce potential holding mortality in the trap box and to assess trap efficiency (which was later abandoned as noted below). At each trap check, the following data were collected:

1. Total catch by species/year class (coho subyearling and yearling, chinook subyearling and yearling, and steelhead smolt).

2. A random subsample of each species/year class was measured for forklength. In large catches, a minimum of 20 individuals per species/year class was measured. In small catches, all individuals were measured.

3. Scale samples were taken biweekly from juvenile chinook and coho salmon (<u>catches permitting</u>) to help assess year classes. We pressed and aged the scales at the Western Washington Fishery Resource Office (WWFRO), and had them verified by WDF personnel.

4. ATPase samples were taken from juvenile chinook and coho biweekly (<u>catches permitting</u>) to help assess migratory readiness. A target minimum of 10 individuals was taken in each field sampling and held on ice (but not frozen) for less than 24 hours in the field, then taken to the Service's Olympia Fish Health Center. At the Center, gill arches from each fish were excised, immersed in preservative solution, and stored in a super-cool freezer (-70° C) until shipment on dry ice to National Marine Fisheries Service (NMFS) at Cook, Washington for ATPase measure (μmoles ATP hydrolyzed per mg protein per hour).

5. After excising gill arches for ATPase analysis (above), the chinook samples were transferred to WDF for otolith (earstone) examination. (Otolith patterns were examined in an attempt to identify early-versus-late emigrants among adult chinook returns.)

6. Injuries among captured fish were noted to infer exit-related injury and mortality. Major injury categories recorded were mortality (any reason), eye injury, bruising, and descaling. Descaling categories followed the criteria developed by NMFS for the Columbia River and consisted of descaled (over 16% scale loss on either side of fish) or partially descaled (3% to 16% scale loss on either side of fish in either a patchy or scattered pattern). Descaling (over 16% scale loss) is considered probable mortality under the Columbia River criteria. Mortalities were noted in all catches, but only a random sample of fish (at least 20 of each species/year class) were examined for injuries in large scoop trap catches.

7. Prior to July, fish caught in the trap were marked with a caudal clip (<u>catches permitting</u>) and released above the trap in an attempt to assess trap efficiency; however, this procedure was

terminated in July due to handling stress and the poor condition of fish captured from that time forward (trap efficiency is discussed further below). The caudal clip consisted of squaring the tip of the fin, sufficient for short-term identification. Fish caught in the afternoon and at midnight were clipped, released above the trap at the dam outlet in the mainstream of the discharge, and recovered in the trap the following morning.

Fyke Traps

To qualitatively assess fish movement into the reservoir, fyke traps were fished approximately one-half river mile upstream of the full-pool reservoir at a railroad bridge in the mainstem, and approximately one river mile upstream of full pool at a road bridge in the North Fork (Figure 1). Routine trapping began on February 18th and concluded on November 30th. Both traps were fished in the same manner as in the 1991 study.

Each trap was of the same design and attached to a bridge. The traps were 6 feet wide and 4 feet high at the mouth, with a 15-foot taper to a 12-cubic-foot floating live box. Net mesh in each was 1/8-inch stretch measure. The mainstem fyke was operated on a "clothesline" anchored to the railroad bridge pylon on either river bank. This allowed us to move the trap into the channel center from a shore position during fishing periods. An electric winch was used to facilitate trap removal when river flow was high. The North Fork trap was also anchored to bridge supports on either river bank, but was lowered into the channel center with a hand winch from the top of the bridge.

Fyke operation and data recording followed that described above for the scoop trap, with several exceptions: midnight trap checks were not feasible during the spring at the mainstem fyke because of hazardous flow conditions; injury recording and efficiency testing (items 6 and 7 under scoop trap operation above) were not conducted with fyke captures.

Other Fish Collections

To augment ATPase sampling at the traps, juvenile chinook were also collected in the forebay of Howard Hanson Reservoir in the vicinity of the intake tower during late summer and early fall. These fish were collected biweekly on hook-and-line as available.

Fish Passage Estimation

Fish passage estimates were derived using the same methodology as in 1991 (Dilley and Wunderlich 1992). We estimated daily fish passage (by species and year class) through each exit of Howard Hanson Dam by apportioning the total daily hydroacoustic passage estimates according to the proportional representation of each species/year class in the scoop trap catches. We used length-frequency and/or scale analyses to determine year classes of chinook and coho salmon captured at the traps. We then computed the proportions of each species/year class observed in each 24-hour scoop catch. These catch proportions were then applied to daily hydroacoustic estimates (midnight-to-midnight). The proportion of each species/year class was applied to the 24-hour hydroacoustic estimate for a given trap day and all succeeding 24-hour hydroacoustic estimates until the next scoop trapping period, and so on.

As in 1991, we used observed (actual) scoop catches rather than expanded scoop catches to apportion hydroacoustic estimates because efforts to determine trap efficiency were not successful. Prior to July, the numbers of fish available to mark were sporadic and too low for trap efficiency assessment. Thereafter, handling losses and poor fish condition (as noted above) prohibited further efficiency testing.

We considered observed scoop catches to be adequate for fish passage estimation in this application because: 1) the scoop trap was consistently fished in the channel center to maximize available flow and velocity into the trap throughout the entire study period, 2) capture of yearling-and-smaller-sized salmonids was consistently accomplished throughout the study period.

Fish Passage Evaluation

We used stepwise linear regression to evaluate fish passage at Howard Hanson Dam in relation to the major variables of dam operation, as in our previous year's study (Dilley and Wunderlich 1992). We evaluated total daily chinook (subyearling) and coho (subyearling and yearling) passage in relation to daily reservoir outflow and exit depth. We also examined fish passage in relation to daily outflow temperature (measured just below the scoop trap) during the summer drawdown periods for 1991 and 1992 to better define baseline passage conditions. In all analyses, we used daily operational data (instantaneous values at 0800 hours) provided by the Corps of Engineers. Significance in all statistical tests was established at $P < 0.05$.

To evaluate relations between fish passage and operational variables, we divided the 1992 fish passage monitoring at Howard Hanson Dam into five major periods based on fish movement and project operation (Figure 5).

1. Pre-refill (February 18 - March 31) when all outflow occurred at the dam's radial gate, and chinook fry were released above the project.

2. Refill (April 1 - May 1) when outflow occurred only at the radial gate until April 8 and only at the bypass gate thereafter.

3. High summer pool (May 2 - June 3) when reservoir elevation remained relatively stable; outflow occurred at both the bypass and radial gates until May 13, then only at the bypass gate.

4. Early drawdown (June 4 - September 25) when outflow only occurred at the bypass.

5. Late drawdown (September 26 - November 30) when outflow occurred at both the bypass and radial gates until September 28, and only at the radial thereafter.

Within the five major periods, we also examined fish passage in relation to operational variables when spikes in emigration (unexpected peaks in emigration which lasted for at least several days) were observed.

The 1992 study periods were similar to those used in 1991, except for these differences in project operation and monitoring approach:

1991	1992
Monitoring occurred 220 days (April 16 to November 22).	Monitoring began sooner and continued for 285 days (February 18 to November 30) to assess early chinook fry movement.
Spring refill occurred relatively late (May 20 to June 21).	Spring refill occurred relatively early (April 1 to May 1) due to drought concerns.
A "test refill" occurred in early May, before spring refill, to assess project effects on coho smolt passage.	No "test refill" was possible because of early refill.
Reservoir refill-and-drawdown cycle lasted 187 days (May 20 to November 22).	Reservoir refill-and-drawdown cycle lasted 244 days (April 1 to November 30).
Bypass exit operated 159 days (May 29 to November 5).	Bypass exit operated 142 days (May 9 to September 28).

RESULTS AND DISCUSSION

Overview

Overall, movement of anadromous salmonids past Howard Hanson Dam in 1992 was characterized by 1) a pulse of fish during the spring months comprised mainly of chinook subyearlings with a moderate number of coho and chinook yearlings, 2) a pulse of coho yearlings in early summer with pulses of chinook subyearlings occurring throughout the summer, and 3) a large pulse of both chinook and coho subyearlings in October and November.

Appendices B, C, and D provide complete listings of catch and effort for scoop and fyke traps. Appendix E lists estimated daily fish passage at the dam, by species and year class, throughout the study period.

Chinook Yearlings

1992 Findings:

An estimated 1,645 chinook yearlings (Table 1) egressed from the reservoir during the study, with emigration occurring from late February to late July (Figures 6 and 7). No yearling chinook occurred after late July, based on length frequency and scale analyses (Table 2) of chinook captured at the scoop trap in late summer and fall. The majority of yearling chinook emigrated in late June approximately two months after normal full reservoir pool (elevation 1145 feet) was achieved. The last recovery at the scoop trap occurred on July 27th (Appendix B). Yearling chinook emigration from February through July is consistent with other Puget Sound and coastal Washington systems (Seiler et al. 1984; Wunderlich et al. 1989). Emigration of 1,645 chinook yearlings represents 0.085% of the 1990-brood chinook fry (1,939,530) released into the upper watershed in 1991.

Timing of yearling chinook passing the dam could not be compared to the mainstem fyke trap catches because only one chinook yearling was captured at the mainstem site.

Chinook yearlings were mainly observed during periods when only the bypass gate was used (May 14 to September 25, Table 1). Fourteen percent of the chinook yearling catch were dead while 37% were descaled or partially descaled (Table 3). In addition, 17% were found to have multiple injuries.

Daily passage of chinook yearlings was not significantly related to any of the operational variables tested during the 1992 monitoring period.

Relation to 1991 Findings:

Different emigration patterns for yearling chinook were evident in 1991 and 1992. In 1991, we observed the majority of chinook yearlings egressing the reservoir by the end of April. This was well before full pool was reached in early June. In 1992, the majority of chinook yearlings did not egress the reservoir until after mid June, which was almost two months after full pool had been reached.

Earlier refill in 1992 may have delayed yearling chinook movement out of the reservoir compared to 1991; however, relatively little data are available on yearling chinook movement and response to exit conditions at Howard Hanson Dam. At the upper Elwha River dam, however, yearling chinook emigrants preferred a surface exit, but approximately 10% of emigrants still selected the turbine intake located 75 feet below the reservoir's surface even when a spillway exit was available (Dilley and Wunderlich 1990).

The 0.085% survival from release to emigration observed in 1992 is approximately twice that observed in 1991 (0.045%). The 1991 estimate was considered conservative because monitoring did not begin until mid April. However, we did not observe significant numbers of yearlings emigrating before mid-April in 1992. The better survival may have been due to a milder winter and spring.

Yearling chinook suffered greater mortality and injury in 1992 than 1991, possibly related to differences in peak emigration. No mortalities were observed for 1991 chinook yearlings, but in 1992 we observed a 14% overall mortality occurring mainly from mid June to mid July. Injuries were light in 1991 (no greater than 8%) as compared to 1992 where 20% were partially descaled and 17% were descaled (Table 3). Earlier peak passage in 1991 (late April) may have favored yearling chinook survival as movement occurred at low winter pool through the radial gates while peak passage in 1992 (late June) occurred at high summer pool through the bypass gate.

In 1991, most yearling chinook egressed before refill occurred, so direct measures of their response to changing exit conditions were not made.

Chinook Subyearlings

1992 Findings:

An estimated 178,996 chinook subyearlings (Table 1) egressed from the reservoir during the study. Emigration occurred sporadically throughout the study period with the major pulses of fish exiting from late March to late April (assumed to be displacement coincident with outplanting, Appendix A), mid June to early July, and during early November (Figure 8). Notably, subyearling chinook passage occurred through much of the summer but subyearling coho did not (Figure 9). Subyearling chinook passage occurred with up to 78 feet of water over the bypass exit and 99 feet over the radial gates (Figures 5 and 8).

Late-summer chinook passage may be explained, at least in part, by changes in forebay distribution over the season. In 1992, gillnetting in Howard Hanson Reservoir revealed that subyearling chinook were distributed more deeply in the forebay in late August than in late May, and the late-August distribution was concentrated at the depth of the bypass exit (Dilley 1993).

Mainstem fyke trap catches suggested that many chinook subyearlings were entrapped or delayed in the reservoir through the summer and into the fall until the reservoir elevation was lowered in November. Fyke catches indicated that migration into the reservoir began in mid February and ended by mid May (Figure 10).

The results of ATPase sampling (Figure 11, Table 4) also strongly suggested that entrapment occurred. ATPase, an indicator of smolt readiness (Table 5), steadily increased in fish sampled from the scoop trap beginning in March to early July when levels of high readiness were measured. The late-June peak in ATPase among fish sampled in the forebay coincided with peak movement through the dam (Figure 8). Fish sampled in the forebay area continued to show relatively high ATPase levels into mid September (Figure 11), after which levels dropped to marginal readiness. While a large pulse of fish egressed in November (Figure 8), their low ATPase values suggested that they were not "natural" emigrants.

During the major operational periods in 1992 (pre-refill, refill, high summer pool, early and late drawdown), daily passage of subyearling chinook (Figure 12) was significantly related to exit conditions during refill, when reduced passage occurred as the dam's outflow declined (April 1 to May 1; $r^2 = 0.19$). During late drawdown, when discharge shifted to the dam's radial gate (September 26 to November 30), increased chinook passage was significantly related to increased outflow ($r^2 = 0.13$).

Specific testing of the late June period, when a huge spike in chinook movement occurred (Figure 12), revealed no significant relation to any exit conditions, but the huge spike may be related to elevated ATPase (Figure 8) and/or the tendency towards deeper forebay distribution near the bypass exit later in the season, as noted above.

Examination of exit temperatures during the summer drawdown period showed no relation to juvenile chinook movement. A maximum exit temperature of 61° F occurred on August 27, which should not influence juvenile chinook emigration (Bell 1991).

Chinook subyearlings emigrating from Howard Hanson project in late fall displayed substantial growth, probably due to reservoir rearing. Mean lengths of subyearling chinook captured in the scoop trap increased from 46 mm in February to 181 mm by late November (Table 6). This compares to a mean size of 190 mm for yearling chinook reared in the upper Elwha River reservoir (Wunderlich and Dilley 1990), and it far exceeds that of stream-reared yearling chinook emigrants in the Skykomish basin (≈110 mm; Seiler et al. 1984).

Late-fall subyearling emigrants from Howard Hanson project were larger than yearling chinook captured in the scoop trap during spring 1992 (Table 6). These spring yearlings were similar in size to Skykomish yearlings. We surmise that the Green River spring yearlings reared in the watershed above Howard Hanson Reservoir after their release in February 1991 and did not attain the size of the late-fall emigrants, which likely entered the reservoir by early-to-mid summer and reared there until drawdown.

Passage of 178,996 chinook subyearlings represents approximately 14.5% of the 1992 release group (Appendix A). Monitoring was terminated on November 30, when the winter pool level of the reservoir exposed the transducers and winter flood conditions posed a danger to scoop trap operations. Visual observations of fish jumping at the reservoir surface after November 30 suggest that a large number of chinook still remained in the reservoir. Total estimates of subyearling chinook passing the dam therefore are probably conservative; some probably emigrated after November 30.

In general, subyearling chinook suffered extremely high dam passage mortality (33%) for the entire study period (Table 3). An 86% mortality was observed for the three days of operation of both the bypass and radial gate (September 26-28). This high rate may have been influenced by already-dead fish, from prior bypass-only operation, washing out of the tailrace below the dam and into the scoop trap. The observed mortality for the prior period (bypass only - from May 14 to September 25) was 37%. We consider the 37% to be far less then the actual rate because many additional dead fish were sighted in the backwater of the tailrace, but we were unable to enumerate them. These observations occurred from about mid-June to mid-July when 40% of the total number of subyearlings passed through the dam.

Among injury categories for subyearling chinook, partially descaled was the most significant at 19%, followed by multiple injuries (9%) and descaling (8%).

Relation to 1991 Findings:

Reduced outflow was apparently the dominant factor influencing slowed chinook passage through Howard Hanson Dam in both 1991 and 1992, but the variation in fish passage explained by outflow was not great (r^2 values ranged from 0.13 to 0.53 in all tests). As well, slowed chinook passage occurred during different periods in 1991 and 1992. In 1991, slowed passage occurred at both high summer pool and the drawdown periods, but not during refill as in 1992. In both years, however, increased passage during the latter stages of the drawdown period was significantly related to increased outflow.

In both years, exit flow temperatures showed no relation to chinook passage during the drawdown period. A maximum temperature of 63° F occurred on August 30, 1991, which should not influence juvenile chinook migration (Bell 1991).

The 14.5% subyearling survival from release to emigration observed in 1992 was substantially higher than the 1.1% observed in 1991. Both environmental and physical factors may have played a role in this increased survival. The 1992 spring weather was considerably milder than 1991. Planting of fry was considerably different between the two years. In 1991, fry were planted from February 21 to March 7, averaged 482 per pound, and the number of fish per release were generally over 100,000. In 1992, fry were planted from February 18 to April 2, had three distinct size groups (483/lb, 267/lb, and 177/lb), and the number of fish per release was no greater than approximately 26,000.

Subyearling chinook did not experience the high rate of mortality in 1991 that was observed in 1992 (7% versus 33%). Of special note is that the average outflow in 1991 for the period of June 15 to July 15 (586 cfs) was more than twice that of 1992 (253 cfs), suggesting reduced outflow was associated with higher mortality in 1992. Outflow during this period in both years occurred at the bypass.

Coho Yearlings

1992 Findings:

An estimated 7,489 coho yearlings egressed from the reservoir during the study (Table 1). Emigration from the reservoir was observed at the start of trapping in late February and continued through May with peak movement occurring in late April and early May (Figure 13). Mainstem fyke catches (Appendix C) indicated movement into the reservoir during the same period (Figure 14), although a large proportion of fyke trap catches occurred from mid-April to mid-May, after the early peak in reservoir emigration ended. A pulse of fish in late July and early August and other smaller pulses at the end of October and through November at the dam (Figure 14) confirmed that entrapment or delay occurred in the reservoir. Approximately 42 percent of the estimated coho yearlings did not emigrate till well past their expected timing (February through June). Previous gillnet sampling in Howard Hanson Reservoir also indicated that yearling coho were entrapped in the summer of 1984 (Seiler and Neuhauser 1985) and in the summer of 1989 (Cropp undated).

The relatively large movement of coho yearlings in late July and early August (Figures 13 and 15) bore no significant relation to any exit conditions. No significant relations between yearling passage and exit conditions were detected over the entire monitoring period.

Coho yearlings recovered at the scoop trap averaged approximately 102 mm forklength during the spring emigration (Table 6), which was consistent with mean lengths in spring 1991 (110 mm) (Dilley and Wunderlich 1992) and in spring 1984 (~105 mm) below Howard Hanson Dam (Seiler and Neuhauser 1985). Yearlings emigrating in November averaged 164 mm.

Passage of 7,489 coho yearlings represents approximately 0.73% of the 1991-brood coho fry released above Howard Hanson Dam (1,028,157) in 1991. This survival value appears low compared to the 1.1% fry-to-smolt survival reported by Seiler and Neuhauser (1985) in their 1984 evaluation of Green River coho fry planting in the upper watershed, and coho fry-to-smolt values (1.3 to 30.1%) reported by Johnson and Cooper (1991) and Smith et al. (1985).

The dominant injury observed for coho yearlings at the scoop trap for the entire study was partial descaling (Table 3). Partial descaling was about 17% higher when the bypass was in operation compared to radial gate operation in early spring, although few fish (12 individuals) were available for comparison during bypass operation. In general, serious coho yearling injury and mortality were low during radial gate operation in the spring. During bypass discharge (May 14 to September 25), high mortality (25%) and partial descaling (25%) were recorded, with a smaller number of fish being descaled (8%) and bruised (8%). In comparison, Seiler and Neuhauser (1985) observed no injury or mortality during radial gate operation, and reported about 3% mortality or severe injury (no details on injuries) among coho smolts during bypass discharge in 1984. A 42% mortality rate was recorded for the three days of operation of both the bypass and radial gate (September 26-28), which may have been the result of previously dead fish, from prior bypass operation, washing out of the tailrace below the dam and into the scoop trap.

Relation to 1991 Findings:

Significant reductions in yearling passage occurred during both test and actual refills in 1991. These reductions were very strongly associated with both outflow and exit depth (r^2 = 0.95 to 0.97). Lack of a comparable association in 1992 may be due to the early refill (early April rather than early June as in 1991), which occurred well before the expected peak in coho smolt emigration in mid May. In effect, poor exit conditions in 1992 associated with early refill probably stopped most yearling emigration in the spring just as it started, and resulted in several pulses of trapped yearlings (Figure 13) during the late summer and late fall which were not seen in 1991.

The 0.73% fry to smolt survival of the 1990-brood fry observed in 1992 is almost twice that observed in 1991 (0.44%) for the 1989-brood fry planted in 1990. The increase observed in 1992, like the increase observed for chinook yearlings, may be due to a milder winter and spring.

During the spring months, yearling coho experienced only minor injuries in 1992, 8% partially descaled and 20% eye injuries, as compared to 1991 when partially descaled fish ranged from 27 to 43% during the same period. No mortality was observed in 1992 for the spring months and less than 1% in 1991. The high mortality observed in 1992 during late July through September could not be compared to 1991 because no yearlings were observed after late June of that year.

Coho Subyearlings

1992 Findings:

An estimated 31,632 subyearling coho egressed from the reservoir during the study (Table 1). Virtually all emigration occurred during the fall (Figure 16). Observations in mainstem fyke trap catches indicated fish moving downriver starting in early April and continuing until mid June (Figure 17). Since coho subyearlings normally do not migrate until the following spring, it is reasonable to assume that these fish were moving downriver due to displacement after release in April and May (Appendix A, Table 7). A corresponding movement at the dam in early spring was not observed and little movement occurred until September through November (Figure 17). This suggested that coho subyearlings were delayed in the reservoir until fall drawdown.

As with subyearling chinook, we surmise that young-of-the-year coho delayed by the dam and reservoir attain large size due to reservoir rearing, in contrast with coho yearling migrants which rear in the watershed above the reservoir for one year prior to typical spring emigration. However, ATPase values for reservoir-delayed coho (Table 7) indicated a very low readiness to emigrate (Table 5), even though mean size of these fish was similar to yearling coho passing the dam in the spring (Table 6).

During reservoir drawdown (both early and late drawdown periods combined), increased outflow (Figure 18) was significantly related to increased coho subyearling passage (r^2 = 0.37). Outflow bore no significant relation to subyearling passage during the spring refill period, which was the only other passage period when these fish were observed. Increased exit depth was significantly related to reduced coho subyearling passage during the refill (r^2 = 0.22), but during no other part of the study period.

Passage of 31,632 coho subyearlings during the study period conservatively represents approximately 3.4% of the 1991-brood fry planted in 1992 above the dam (Appendix A). Further subyearling emigration probably also occurred after the end of monitoring on November 30.

The dominant injury observed among subyearling coho over the study period at the scoop trap was partial descaling (Table 3). Of the two species (chinook and coho) and two year classes (1+ and 0+), subyearling coho had the lowest observed mortality rate (5% overall), possibly because most of these fish passed the dam via radial gate rather than bypass gate. However, subyearling coho experienced the highest rate of partial descaling (32%).

Relation to 1991 Findings:

In both years, increased outflow was significantly related to increased coho subyearling passage. This phenomenon was observed during final drawdown in 1991 and during the total drawdown in 1992. However, subyearlings were inexplicably absent during early stages of drawdown in 1991, but present throughout the drawdown period in 1992 (Figure 18).

The emigration of 3.4% of the 1991-brood fry planted in 1992 was about the same as observed in 1991 (3.1%). In both years, further emigration probably occurred after monitoring ended in November.

Observed passage mortality for subyearlings over the entire 1992 period (5%) was more than double that of 1991 (2%). Almost all mortalities occurred prior to November in 1991, whereas most mortality occurred in the month of November in 1992, when most passage in that year also occurred.

Steelhead

1992 Findings:

An estimated 32 steelhead smolts egressed from the reservoir during the study (Table 1). Given the low number of steelhead captured in the scoop trap (4 total smolts; Appendix B), the apportioned hydroacoustic estimate (32) may not adequately represent total steelhead abundance or emigration timing as implied in Table 1.

Few scoop trap captures of steelhead may be explained by several factors. First, in a previous evaluation of steelhead passage at Howard Hanson Dam (Seiler and Neuhauser 1985), a total of 181 naturally reared smolts were captured during spring of 1984, with a late-April to mid-May peak in abundance. The 1984 recoveries were based on continuous operation of the trap from April 1 to June 15. In 1992, the frequency of scoop trap operation was only twice per week, far less than that of 1984.

A second factor in low steelhead captures at the scoop trap was that stream velocities were lower during portions of the 1992 emigration compared to the 1984 season. As steelhead smolts require the highest velocity of all anadromous salmonids to maximize scoop trapping efficiency (7 to 8 feet per second, optimally), a lower recovery rate may be expected at the Howard Hanson trap site in 1992 than in 1984. Figure 4 shows velocities measured at the scoop trap over the 1992 season.

A third factor in low steelhead captures was that fewer steelhead fingerlings were released in 1990 than in 1982 (32,562 versus 46,880 fingerlings) which would reduce expected smolt production, all other factors being equal.

A fourth factor in low steelhead captures at the scoop trap was that early refill may have hindered passage of smolts as was observed for juvenile salmon, although we gathered no empirical evidence of impaired steelhead passage during this study or in our previous year's study when refill occurred relatively late at the Howard Hanson project (in early June). However, Seiler and Neuhauser (1985) reported fewer scoop-trap captures of steelhead below Howard Hanson Dam after refill was underway in early June 1984 (compared to earlier springtime captures), but fewer steelhead captures could also be associated with waning natural emigration by that date. As noted below, at other projects steelhead smolts preferred a surface exit if available.

Relation to 1991 Findings:

As in 1991, very few steelhead were recorded for the reasons outlined above. Since the 1990 release was even smaller than the 1989 release (32,562 versus 46,530), a smaller number of steelhead smolts might be expected (32 versus 259) for 1992.

Other Salmonids

Scoop trap catches of other salmonids were minimal and scattered throughout the study. A total of 22 rainbow trout and 15 cutthroat trout were recorded. Forklengths of rainbow trout ranged from 42 to 240 mm, and forklengths of cutthroat trout ranged from 81 to 185 mm. These fish were not used in the apportioning of the hydroacoustic counts because their numbers were negligible and they were assumed to be from a resident population below the dam based on their morphology and coloration, although we recognize that identification of steelhead smolts can be problematic (Winter 1992). Similar numbers (31 rainbow and 14 cutthroat trout) and lengths of fish were observed in 1991 scoop trap catches.

Relation to Other Dam-and-Reservoir Projects

Delays in fish passage observed during our 1991 and 1992 evaluations at Howard Hanson project have been observed in similar projects elsewhere in the region. Effects of emigration delay may be site- and stock-specific, however. The following is a brief comparison to other regional projects where information was available.

In passing Howard Hanson reservoir, we believe juvenile anadromous fish favor the shoreline and prefer a surface exit. Beginning in mid-summer at elevated pool levels, we observed juvenile chinook milling in the forebay area of Howard Hanson in both years, and preliminary results of the 1993 Howard Hanson fish distribution study (S. Dilley, U.S. Fish and Wildlife Service, WWFRO, personal communication) suggested more near-shore than deep-water fish distribution. Gillnetting in the Howard Hanson forebay in 1992 indicated a near-surface distribution of subyearling chinook in early summer (Dilley 1993).

Similar observations have been made elsewhere in the region. In the Willamette Valley of western Oregon, anadromous smolts preferred surface exits (approximately upper 15 feet) during spring at Green Peter, Foster, Cottage Grove, North Fork and Fall Creek dams (Korn et al. 1967; Korn and Smith 1971; Wagner and Ingram 1973; Smith 1990). Emigrants also favored the shoreline in passing Willamette Valley reservoirs, and impoundments with long shorelines were less effective in passing fish than those with short shorelines (Smith 1990).

In western Washington, exit preference of chinook, coho, and steelhead smolts was examined in a series of studies at Glines Canyon Dam on the Elwha River. Glines Canyon Dam has a surface exit (20-feet-deep spill gate), and a deep-water exit in the forebay (a turbine intake which is continuously submerged 75 feet). Approximately 89% of all chinook (subyearling and yearling) chose the surface exit over a 15-month emigration period, even though most outflow occurred at the deep-water exit (Dilley and Wunderlich 1990). Rate of juvenile chinook passage through the spillway was not strongly related to spill volume, but interruption of spill in late summer (the peak of Elwha subyearling chinook emigration) virtually stopped all chinook passage through the dam. Likewise, from 91 to 98% of coho and steelhead smolts chose the surface exit of Glines Canyon Dam under similar conditions (most outflow at the deep-water exit) over three seasons of spring emigration (Dilley and Wunderlich 1987; Wunderlich and Dilley 1988; Wunderlich et al. 1989). Rates of coho and steelhead passage were much more strongly related to surface exit flow than were rates of subyearling chinook passage.

Elsewhere in western Washington, preference for surface exit was also observed for coho smolts at the upper Baker dam (Steve Franzen, U.S. Fish and Wildlife Service, Division of Ecological Services, personal communication), for fall chinook and coho at Mayfield Dam (Stober 1986), for coho at Merwin Dam (Hamilton et al. 1970), and for coho and steelhead at Wynoochee Dam (Dunn 1978).

Lack of a surface exit from a reservoir may cause emigrants to seek a deep-water exit or residualize in the reservoir until exit conditions become favorable for passage. At Howard Hanson in 1991 and 1992, we observed a much-protracted emigration of chinook and coho compared to expected spring/early summer outmigration of these stocks in the Green River (Grette and Salo 1986), and we believe that emigrants were delayed until fall drawdown due to lack of a surface exit. Fish passed the dam's deeply submerged exits (up to 77 feet submergence of the bypass exit) only sparingly until reservoir levels declined and outflow increased in late fall of both years.

Similarly, a series of early studies at Mud Mountain Dam on the White River revealed that high reservoir levels during spring and early summer stopped emigration of chinook and coho, as the only exit available for fish passage was submerged up to 180 feet (Heg 1953; Dunston 1955; Maib and Dunston 1956; Regenthal and Rees 1957). At lesser exit depths, however, subyearling chinook and yearling coho passed the project. Over a 100-day period, most chinook subyearling and coho yearling emigrants passed the project at a mean exit depth of 118 feet, but less than 10% passed the project at a mean exit depth of 160 feet (Regenthal and Rees 1957). However, some delay of emigrants was reported at all levels of exit submergence. Emigrants included naturally reared yearling and subyearling chinook and coho of White River stock but, interestingly, many specific chinook tests (including those reported above) were made with Green River fingerlings released in May above the reservoir. Increased outflow coincident with lowering reservoir levels was also believed related to increased emigration (Dunston 1955; Maib and Dunston 1956).

Delayed emigration of chinook and coho until drawdown was also observed in several Willamette Valley projects with similar operational regimens as Howard Hanson's. At Blue River Dam, spring refill submerges the dam's exits 230 feet. Subyearling chinook are outplanted in the reservoir in May for rearing until fall drawdown in late November/early December, when peak emigration occurs, which is positively related to the dam's outflow. Smaller subpeaks in emigration also occur in late August, however, with the dam's exits still submerged 200 feet (Downey and Smith 1990). At Cottage Grove and Fall Creek projects, spring refill submerges the dams' regulating outlets approximately 60 and 160 feet, respectively, and the bulk of subyearling and yearling coho emigration through the projects does not occur until fall drawdown coincident with increased outflow and lowering reservoir levels (Korn and Smith 1971).

Emigrants delayed in reservoirs may experience considerable growth, such as reported here for Howard Hanson. Korn and Smith (1971) and Korn et al. (1967) observed better growth of juvenile salmonids in Oregon reservoirs than in tributaries to the reservoirs, and growth was similar in both old and new impoundments. Downey and Smith (1990) reported excellent growth of impounded subyearling chinook in Blue River Reservoir, and Hamilton et al. (1970) observed excellent growth of subyearling coho rearing in Merwin Reservoir.

Attendant with high growth rates due to reservoir delay, such as at Howard Hanson, is the possibility of early maturity and possible residualism (Thorpe 1987). Failure to emigrate is a possible outcome, as suggested for delayed coho in the upper Cowlitz River reservoirs (Stober 1986). In Wynoochee Reservoir, due to inefficient passage, Mathews (1980) estimated 76% residualism of subyearling chinook and Dunn (1978) estimated up to 63% residualism of coho smolts. Conversely, Regenthal and Rees (1957) suggested that, because Mud Mountain Reservoir is not a year-round impoundment, salmon emigrants may more readily exit the project due to lack of a rearing fish population and prey base, so residualism may be less than in year-round impoundments.

Survival of hatchery fish after stocking in the upper Green River and other northwest streams is variable, however, being a function of a number of factors. These include stream productivity, habitat quality, annual variability in flow and/or weather conditions, the physical condition of hatchery fish and their ability to acclimate to stream conditions, disease, genetics (origin of stock), and stocking practices and techniques (Steward and Bjornn 1990; Smith et al. 1985; Wunderlich 1982).

Predation on delayed emigrants, such as at Howard Hanson, can also be significant (especially if warm water predators are present). Significant reductions in rearing salmon due to reservoir predators were observed in Lake Merwin (Hamilton et al. 1970), the upper Cowlitz reservoirs (Stober 1986), Green Peter Reservoir (Smith 1990), and Cottage Grove Reservoir (Korn and Smith 1971).

SUMMARY

Our principal findings were:

Overall

Movement of anadromous salmonids past Howard Hanson Dam was characterized by 1) a pulse of fish during the spring months comprised mainly of chinook subyearlings with a moderate number of coho and chinook yearlings, 2) pulses of chinook and coho yearlings in early summer with pulses of chinook subyearlings occurring throughout the summer, and 3) a large pulse of both chinook and coho subyearlings at final drawdown in the fall. During monitoring of the dam's exits from mid-February until the end of November of 1992, we estimate passage of approximately 1,645 yearling chinook, 178,996 subyearling chinook, 7,489 yearling coho, 31,632 subyearling coho, and 32 steelhead smolts. Some passage of subyearling chinook and both yearling and subyearling coho was believed to occur after our monitoring period, so these estimates may be somewhat conservative. All species and year classes experienced significant mortality for the entire period (5 to 33%) with chinook subyearlings suffering the most and coho subyearlings the least.

Yearling chinook

Yearling chinook passage occurred in the spring approximately two months after project refill. Based on their size and emigration timing, they likely reared in stream habitat since their release in the upper Green River watershed in 1991. Daily passage of chinook yearlings was not significantly related to any of the operational variables tested during the 1992 monitoring period.

Subyearling chinook

Subyearling chinook passage occurred throughout the monitoring period, with a substantial proportion (72%) exiting the dam during the spring and early summer. ATPase values suggested that fall emigrants were probably trapped in the reservoir since refill, as volitional movement from tributaries occurred by late spring/early summer. These trapped fall subyearling migrants were large (over 180 mm forklength), but exhibited relatively low ATPase levels (smolt readiness). Daily passage of subyearling chinook was significantly related to exit conditions only during the spring refill period, when reduced passage occurred as the dam's outflow declined. During the latter portion of the total drawdown period, when discharge shifted to the dam's radial gate, increased chinook passage was significantly related to increased outflow. Specific testing of passage for late June showed no significant relation to any exit conditions, but may be related to migratory readiness.

Yearling coho

Yearling coho emigration occurred primarily in February through May. The size (≈102 mm forklength) and emigration timing of yearling coho suggested that they had reared in the upper watershed above the reservoir since their release in 1991. No significant relations between yearling passage and exit conditions were detected for the entire monitoring period. Approximately 42% of yearling coho passed the dam after June, with substantial pulses observed in late July and early August.

Subyearling coho

Virtually all subyearling coho passed the dam at fall drawdown (97%). Fyke trap catches suggest that these late emigrants were delayed in the reservoir through the summer until the final fall drawdown. The size of subyearling coho at fall drawdown (≈116 mm forklength) was similar to that of yearling coho smolts emigrating in the spring of 1991 and 1992; however, these subyearlings exhibited very low ATPase levels. Over the monitoring period, greater reservoir outflow at final fall drawdown was significantly related to greater subyearling coho passage at the dam, accounting for 37% of the variation in passage observed during this period. Greater exit depth was significantly related to reduced passage during the spring refill, but during no other part of the study period (nor any of 1991) and for no other species/year class in 1992. Reasons for this singular relation between exit depth at spring refill and subyearling coho passage are uncertain.

Steelhead

Low numbers of steelhead smolts in scoop trap catches adversely affected our hydroacoustic-based estimate of steelhead abundance. Low steelhead catches were possibly related to trapping effort, trapping efficiency, release group size, and hindered passage after refill.

Key comparisons to 1991 findings were:

1) Prior to spring refill, fish displaced from release sites passed the dam relatively quickly during the monitoring periods in each year.

2) Spring refill caused substantial delay and/or entrapment of juvenile salmon, resulting in major late-fall emigrations of fish with low migratory readiness in both years.

3) Peak natural emigration of chinook occurred in late spring to early summer in both years, contributing to their delay and/or entrapment because refill was already completed by that time.

4) Overall survival of subyearling chinook to the dam was much greater in 1992, possibly due to milder weather conditions and/or

differences in release strategies; however, overall survival in passing the dam was much lower in 1992, perhaps due to reduced exit flows.

5) Steelhead smolt observations were insignificant in both years.

6) Relations between fish passage and operational variables (exit flow and exit depth) were less apparent in 1992 (Table 8), perhaps because the earlier refill reduced the range in exit flow and exit depth which outmigrants encountered.

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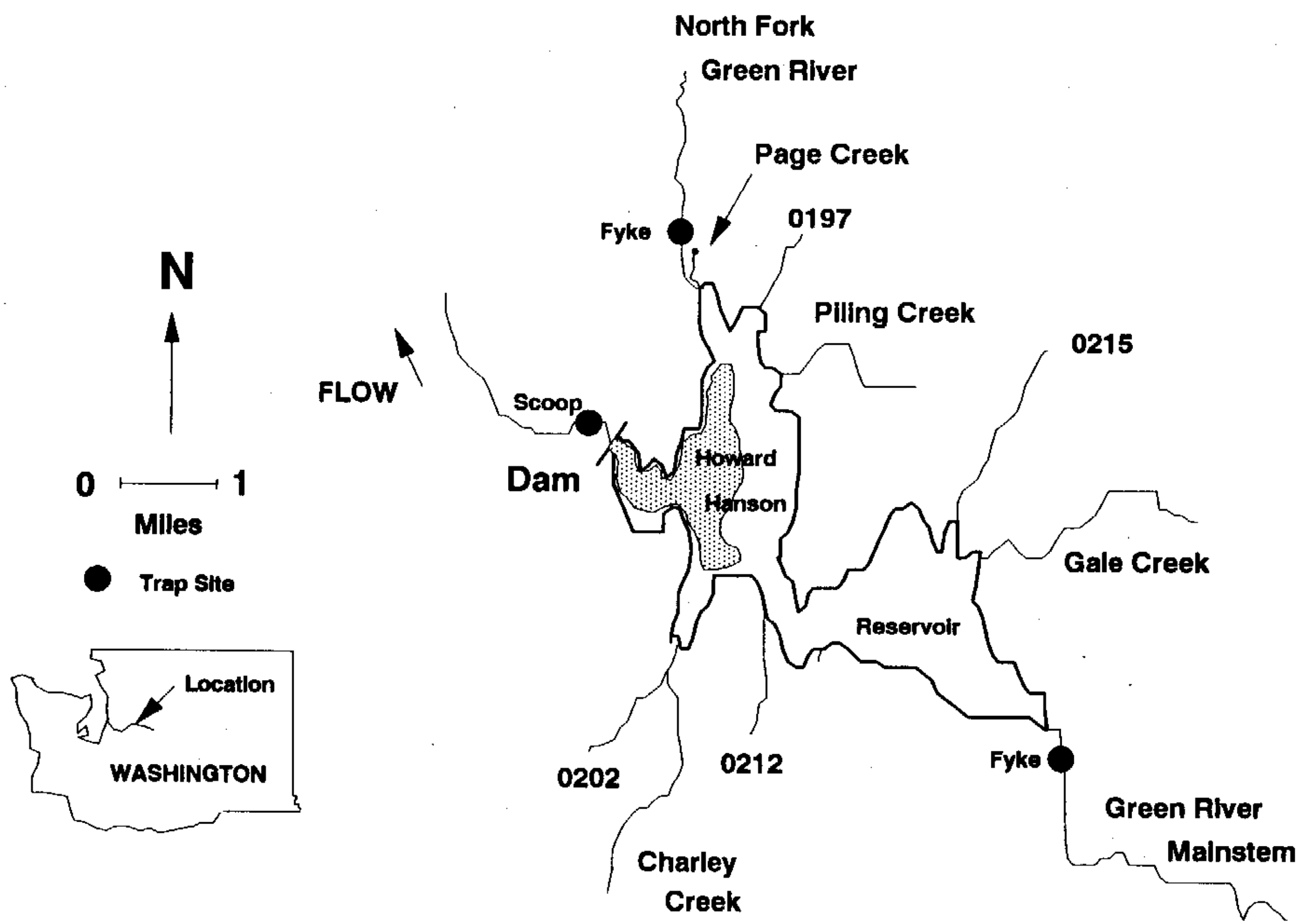

Figure 1. Howard Hanson Reservoir (at summer high pool) showing trap sites and principal tributaries. Winter low pool is shaded. (Map scale is approximate.)

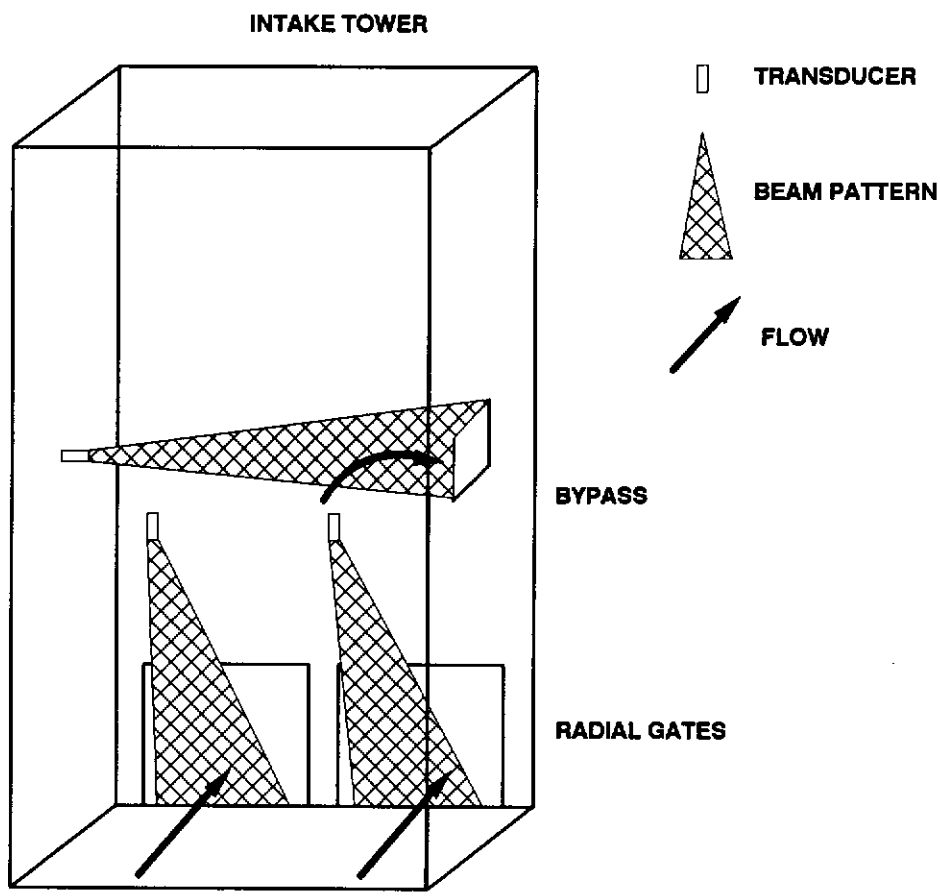

Figure 2. Schematic of the lower section of Howard Hanson Dam intake tower showing approximate locations and beam patterns of transducers relative to radial gates and bypass. Drawing is not to scale.

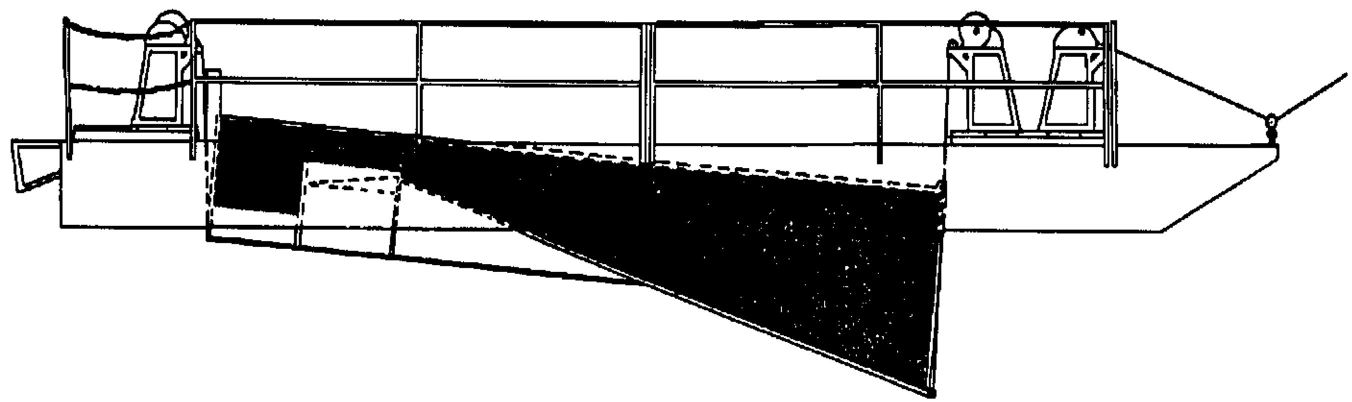

Figure 3. Side view of the scoop trap in fishing position (Source: Seiler et al. 1984.).

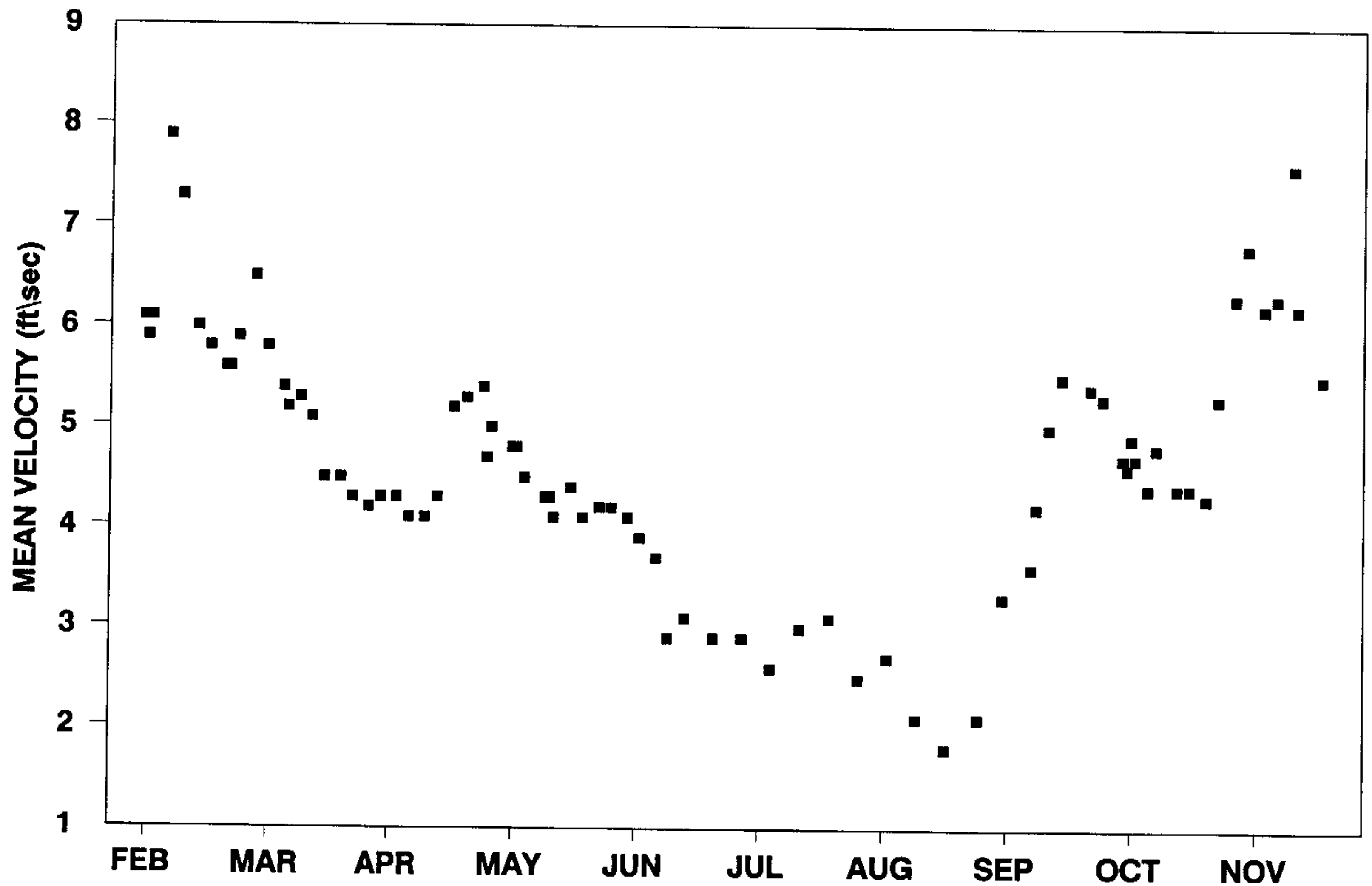

Figure 4. Mean water velocities measured at the mouth of the scoop trap.

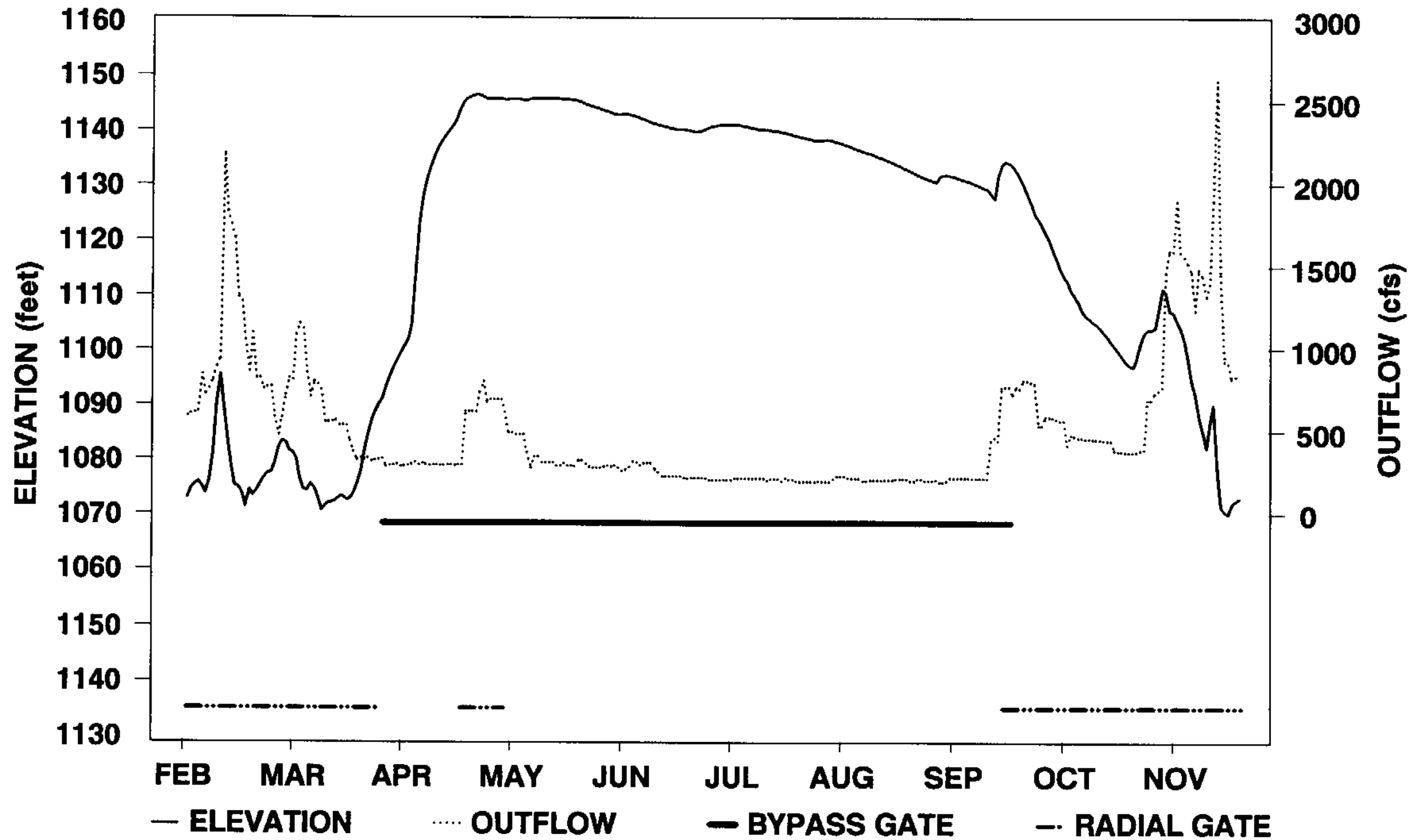

Figure 5. Outflow, reservoir elevation, and periods of gate operation at Howard Hanson Dam during the study period. Mid-months are shown.

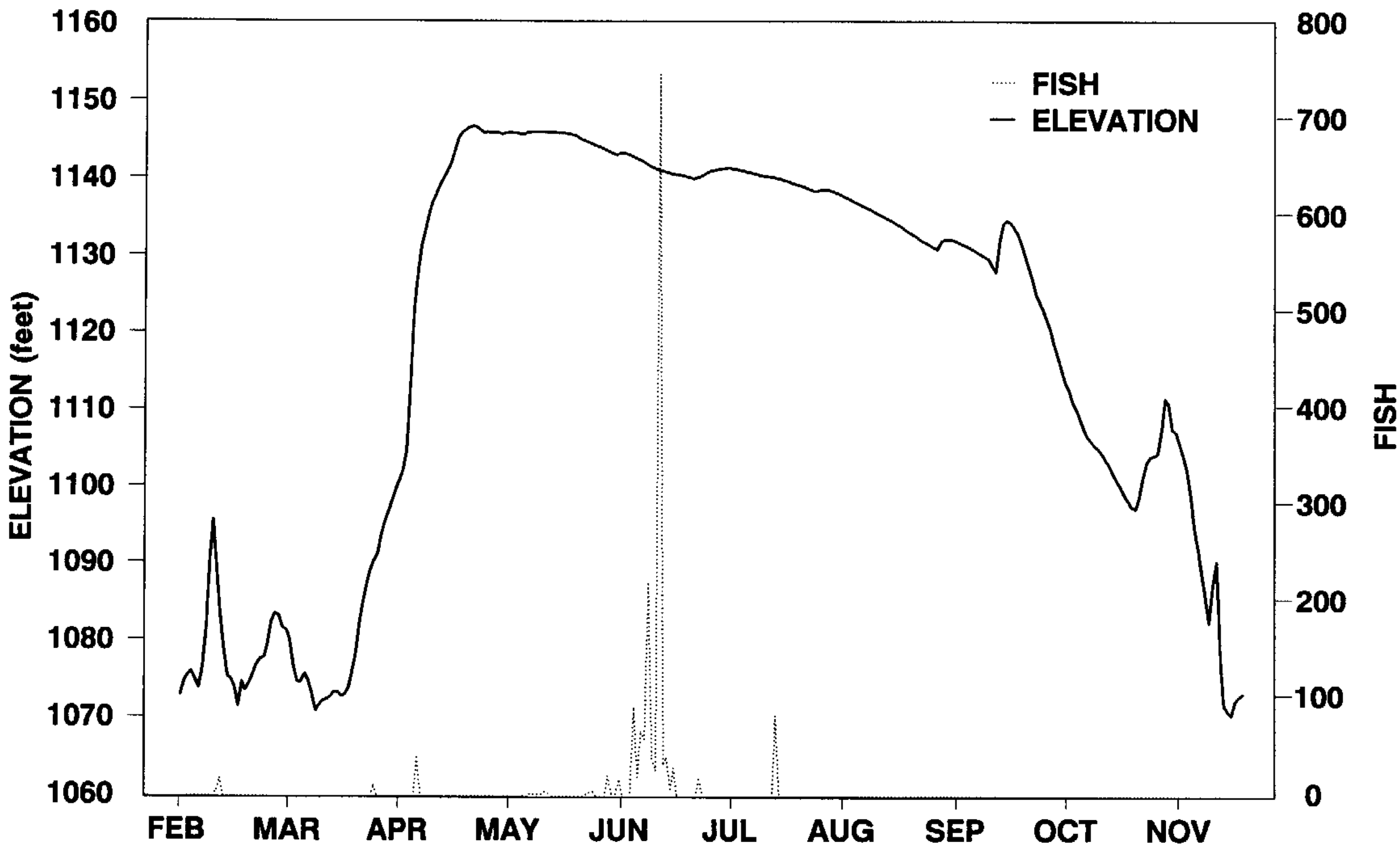

Figure 6. Yearling chinook passage and reservoir elevation at Howard Hanson Dam. Mid-months are shown.

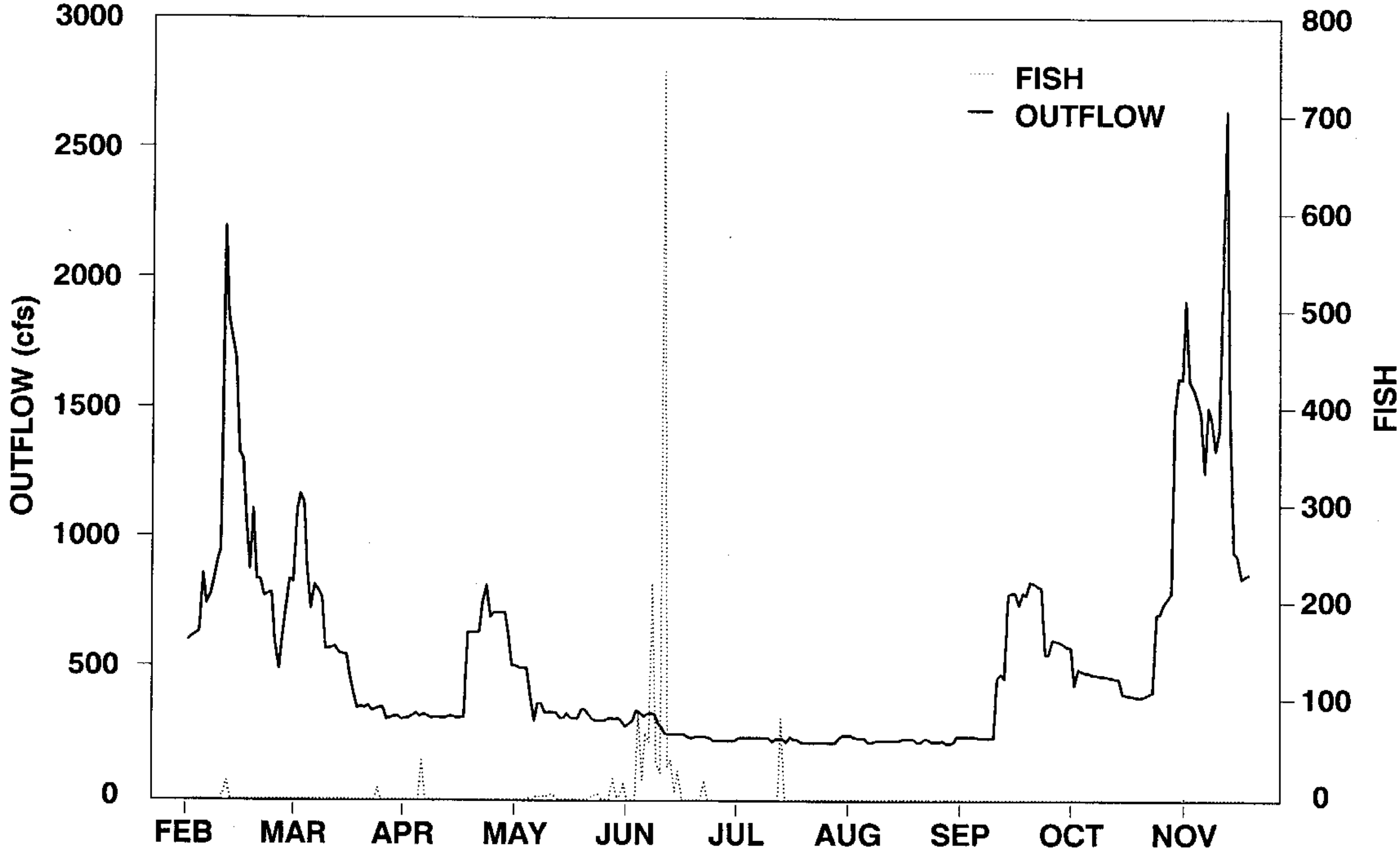

Figure 7. Yearling chinook passage and outflow at Howard Hanson Dam. Mid-months are shown.

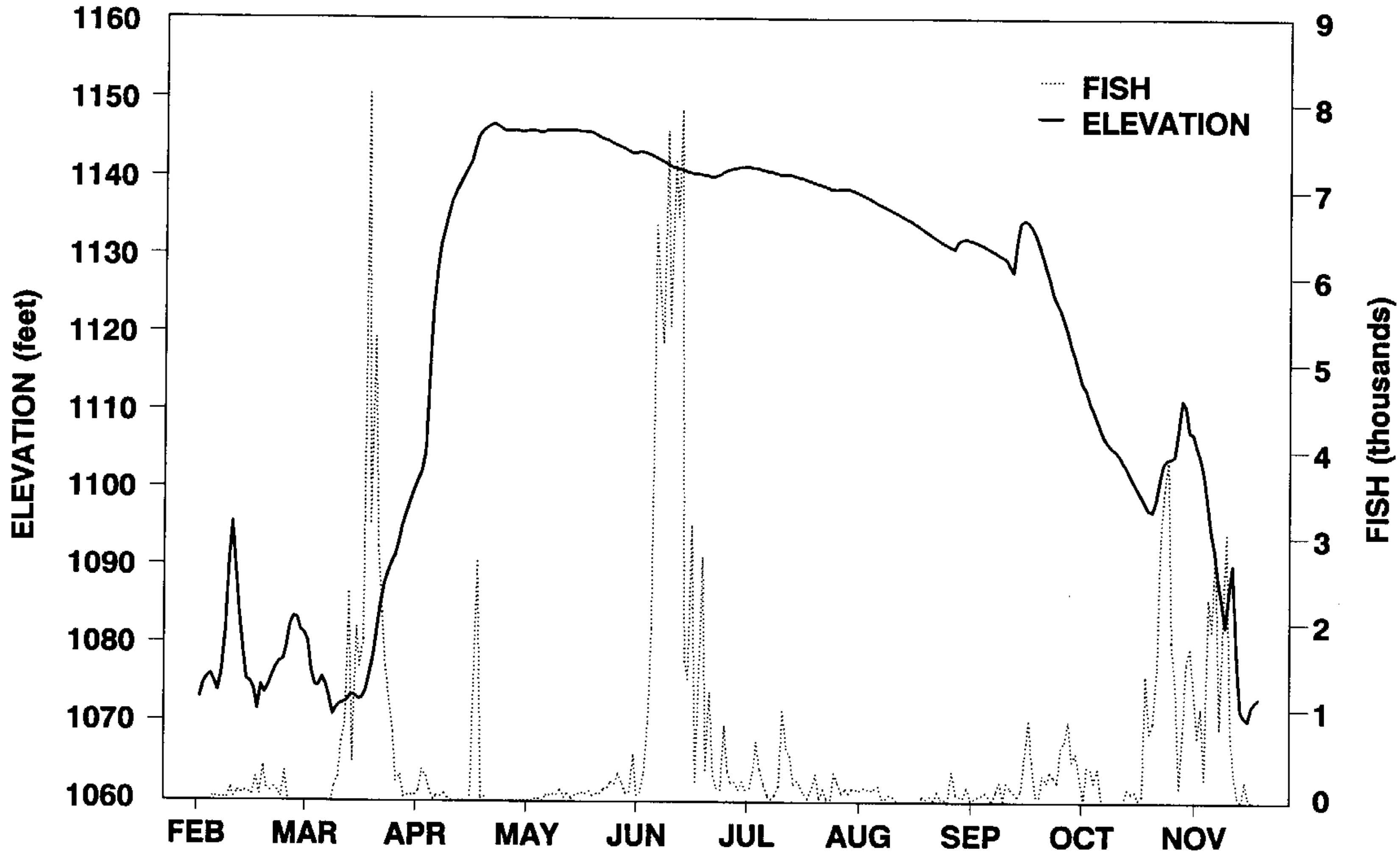

Figure 8. Subyearling chinook passage and reservoir elevation at Howard Hanson Dam. Mid-months are shown.

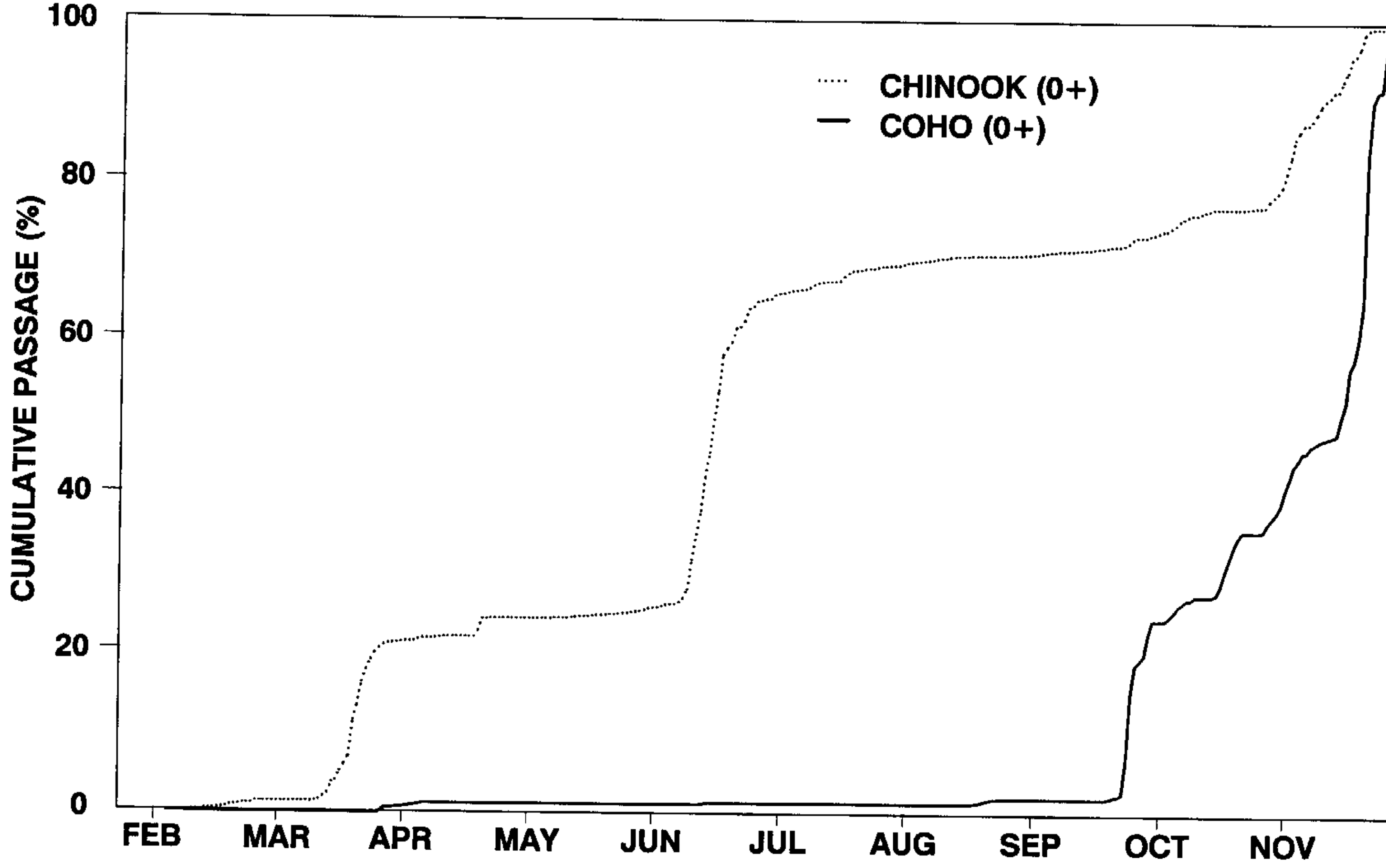

Figure 9. Cumulative passage of subyearling coho and chinook.

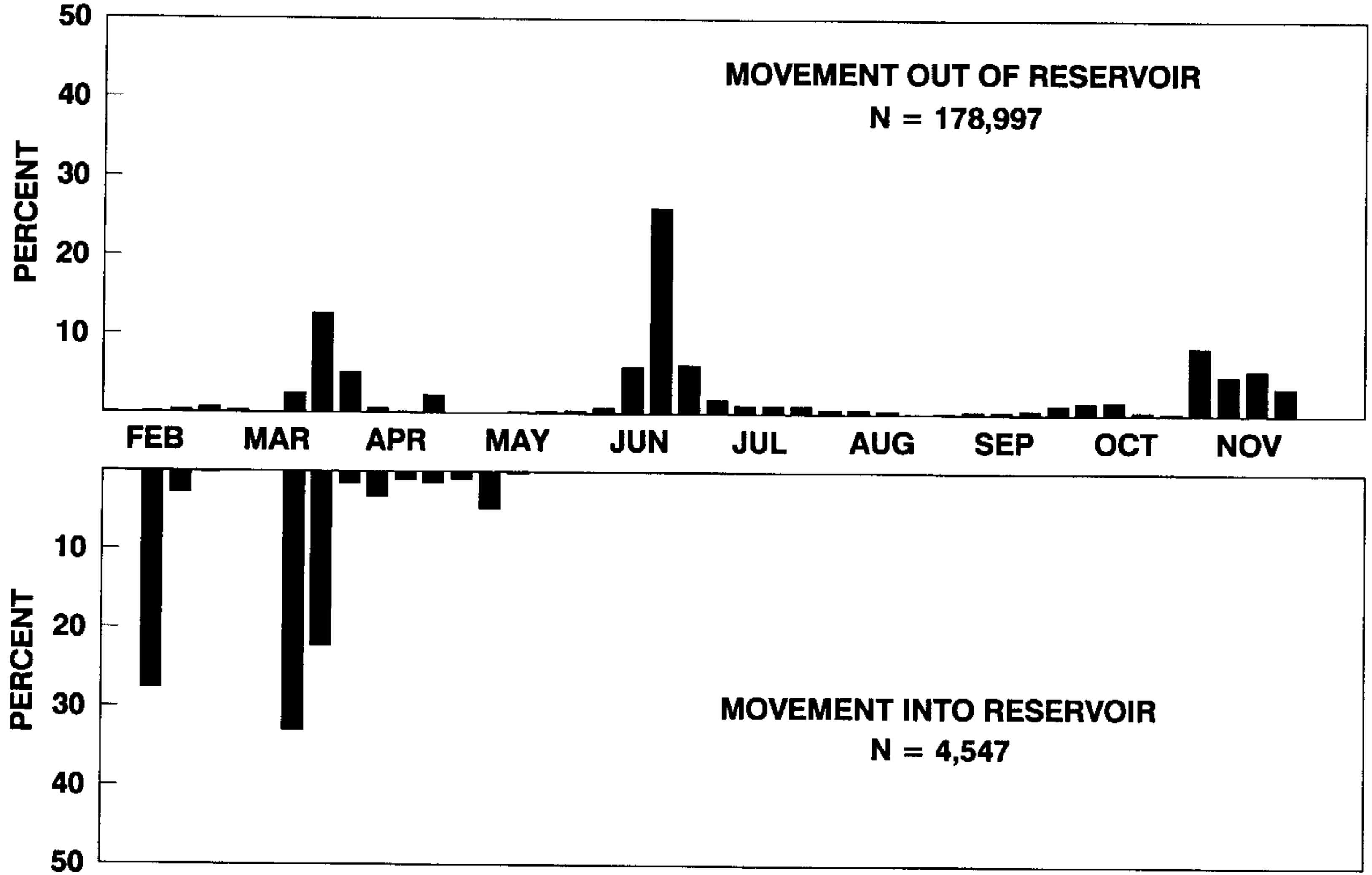

Figure 10. Weekly percentages of chinook subyearlings moving into and out of Howard Hanson Reservoir based on mainstem fyke catches and hydroacoustic/scoop trap estimates. Mid-months are shown.

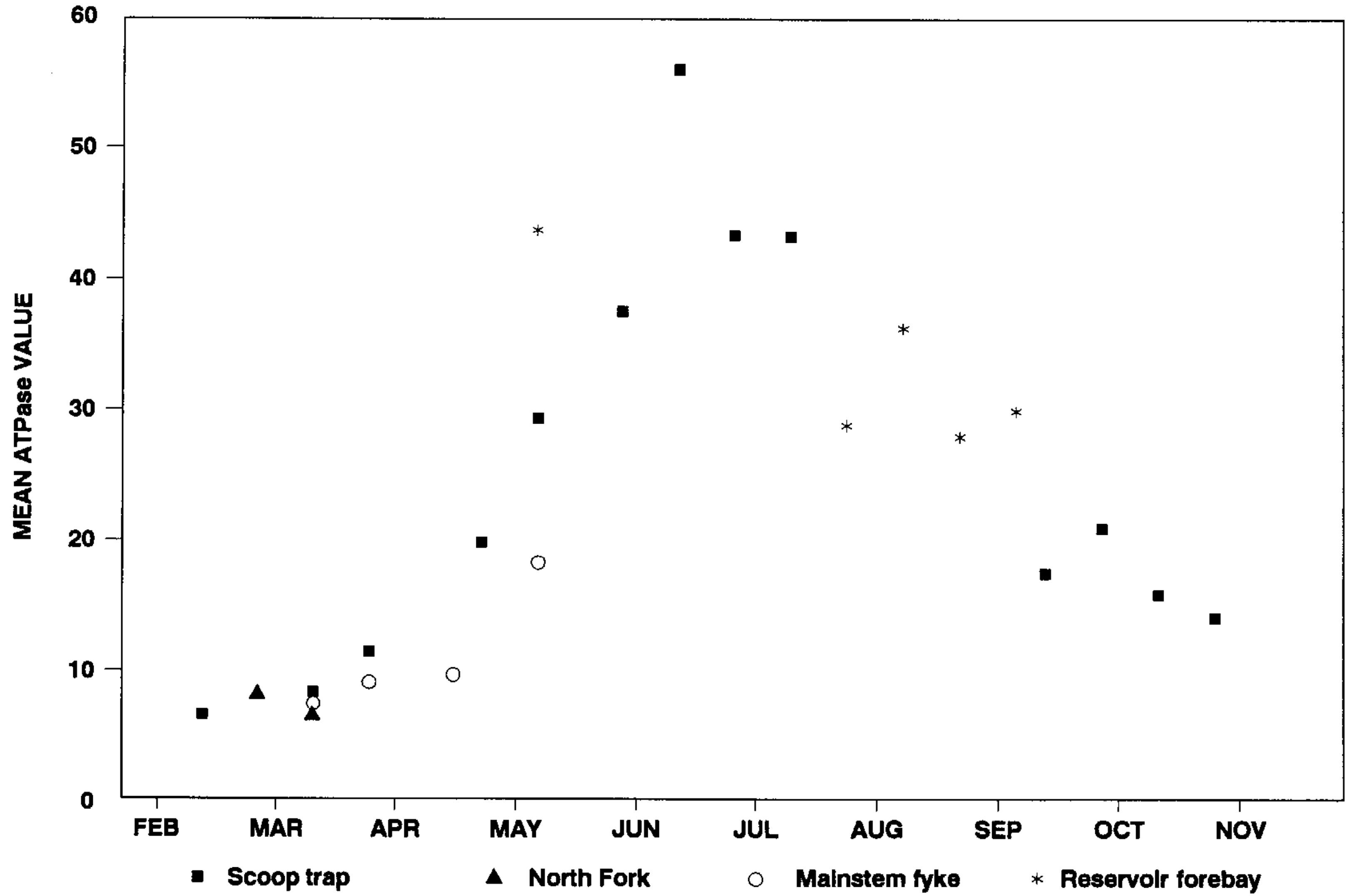

Figure 11. Mean ATPase values for subyearling chinook collected in the Howard Hanson Dam area.

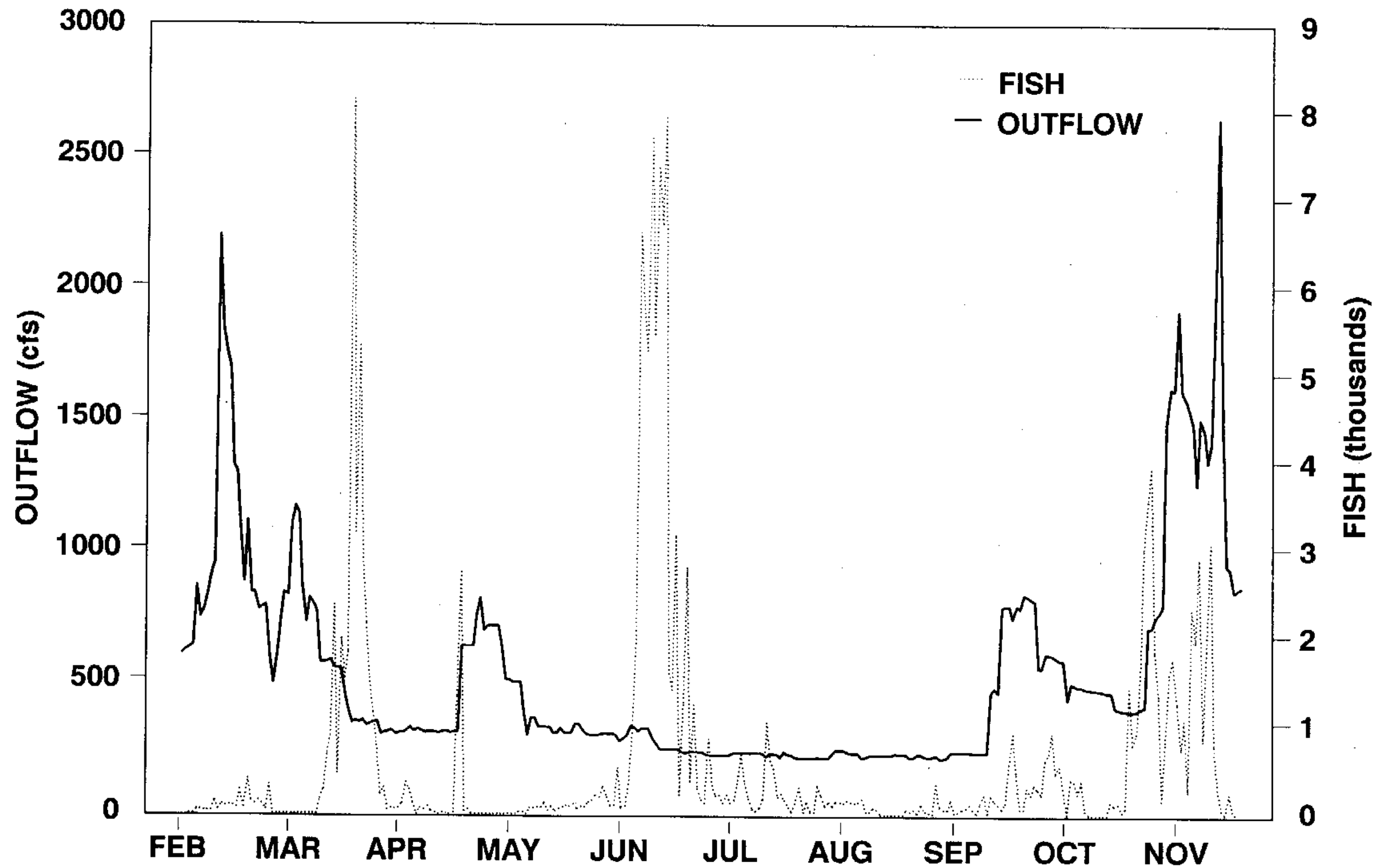

Figure 12. Subyearling chinook passage and outflow at Howard Hanson Dam. Mid-months are shown.

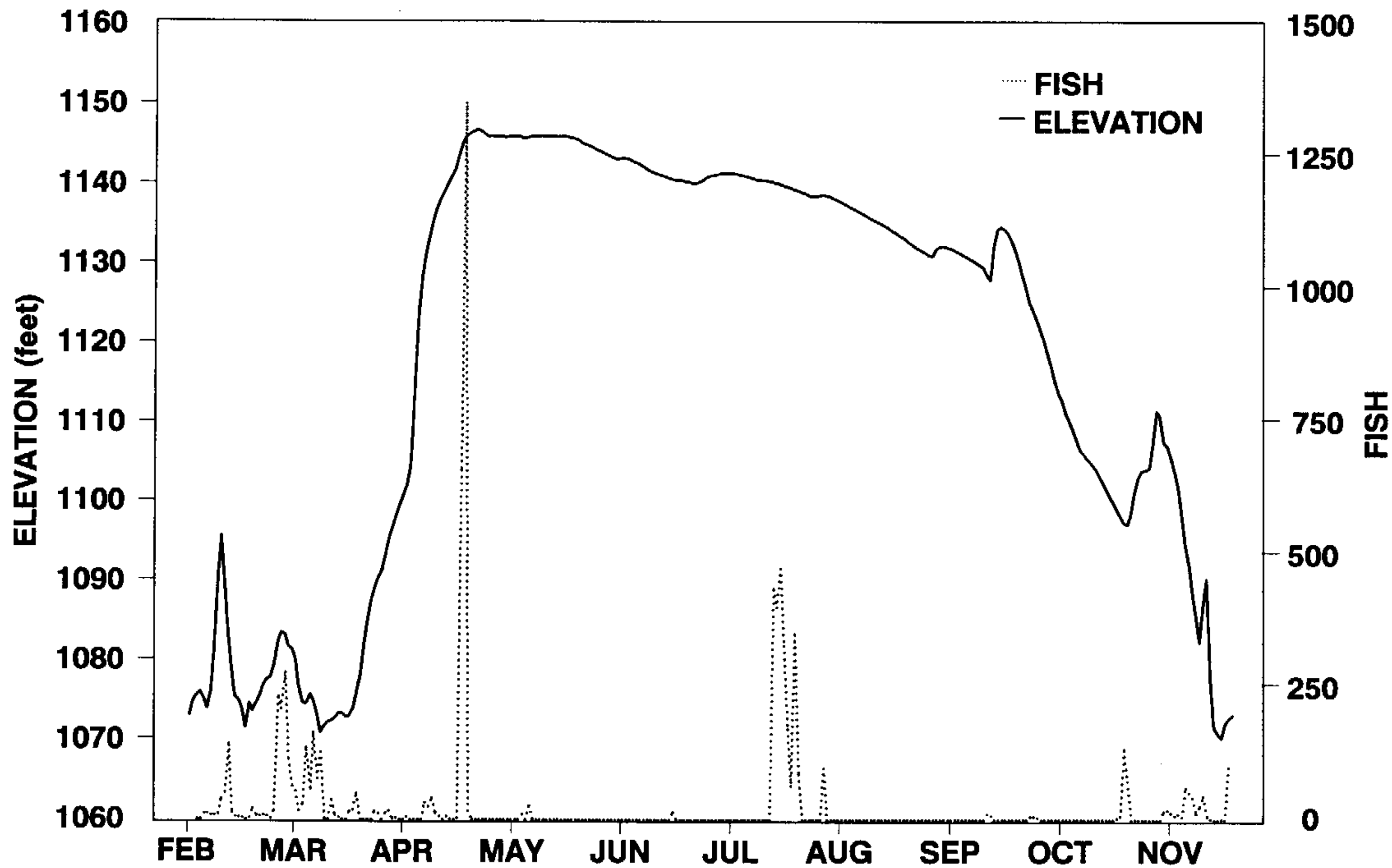

Figure 13. Yearling coho passage and reservoir elevation at Howard Hanson Dam. Mid-months are shown.

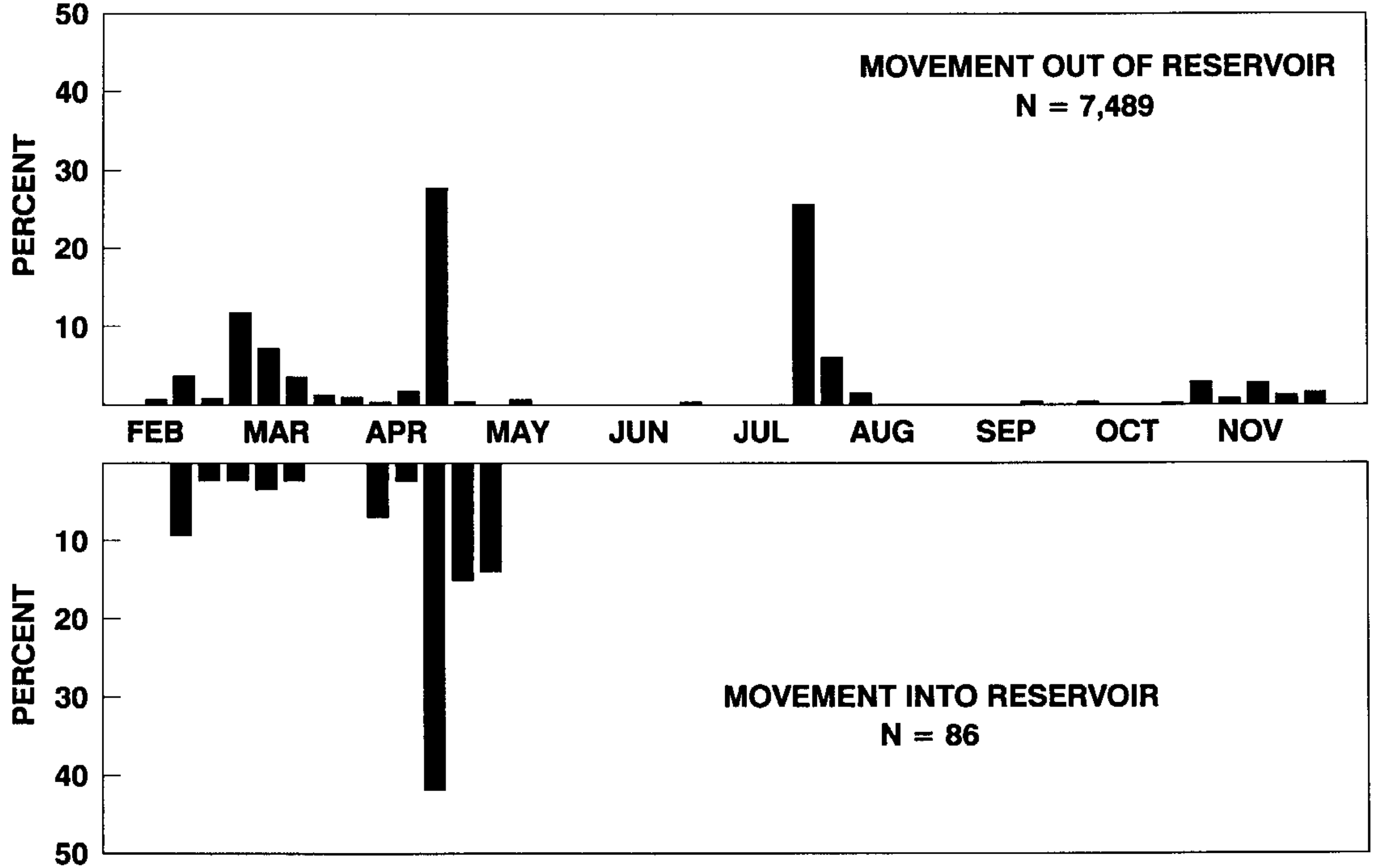

Figure 14. Weekly percentages of coho yearlings moving into and out of Howard Hanson Reservoir based on mainstem fyke catches and hydroacoustic/scoop trap estimates. Mid-months are shown.

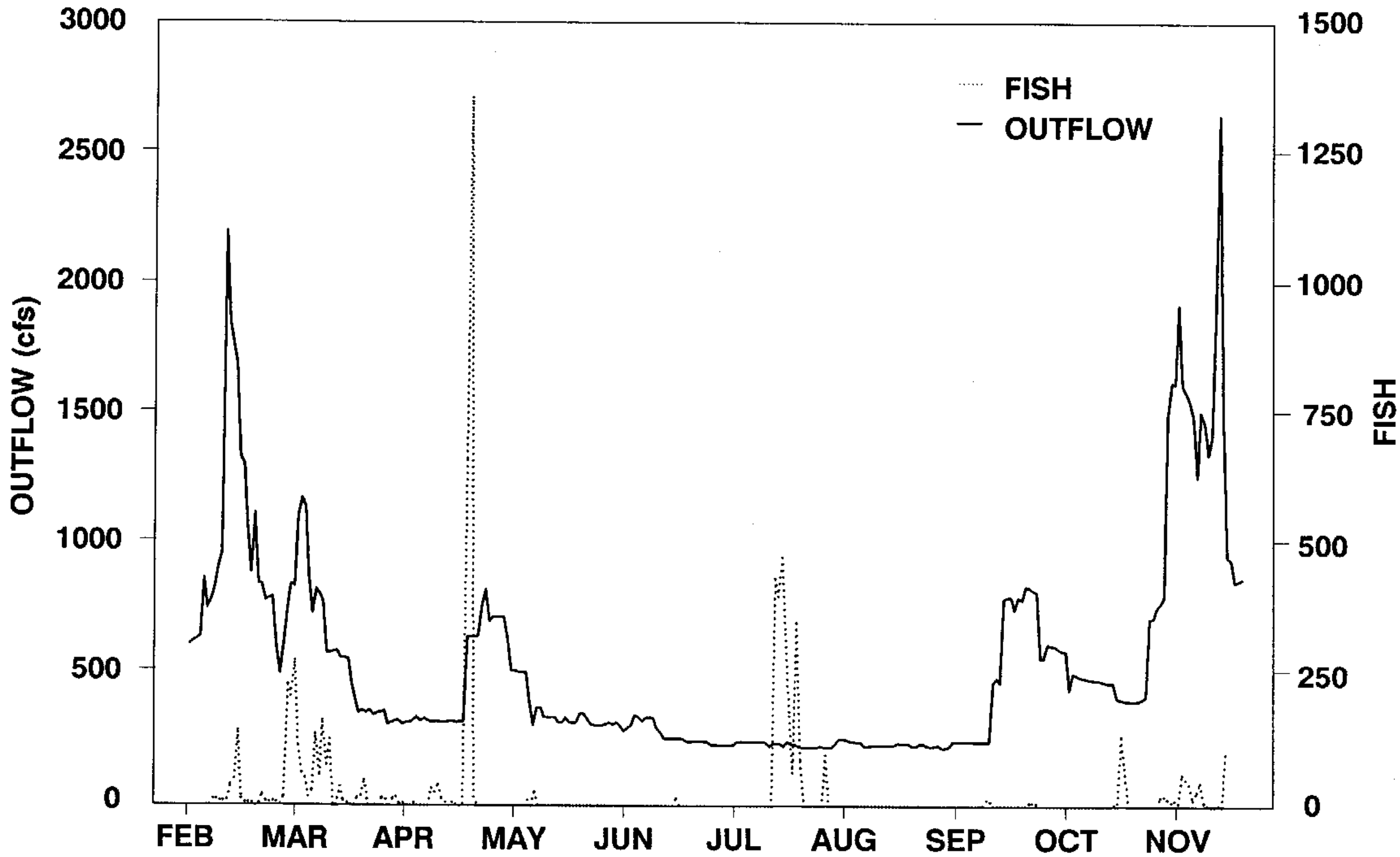

Figure 15. Yearling coho passage and outflow at Howard Hanson Dam. Mid-months are shown.

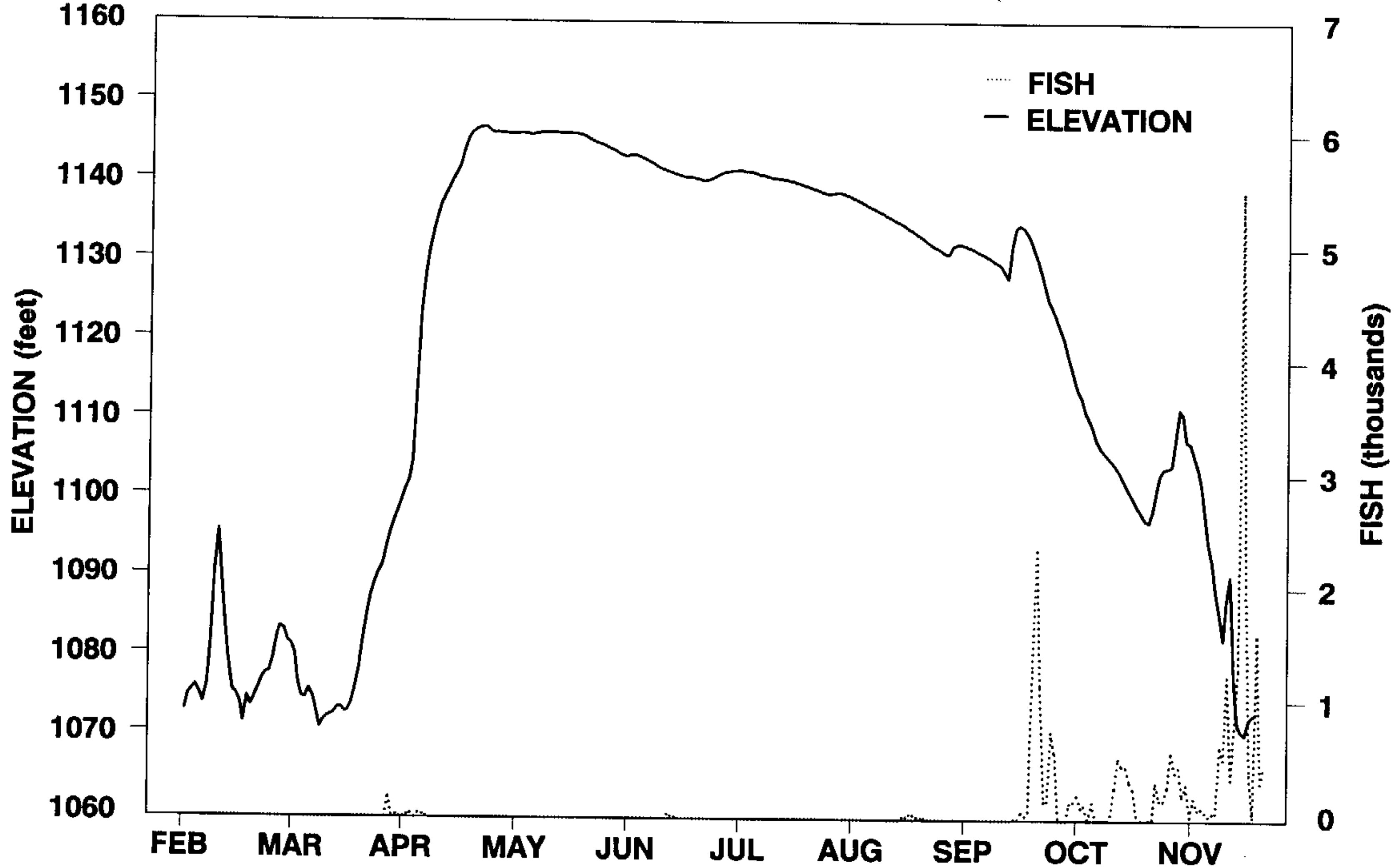

Figure 16. Subyearling coho passage and reservoir elevation at Howard Hanson Dam. Mid-months are shown.

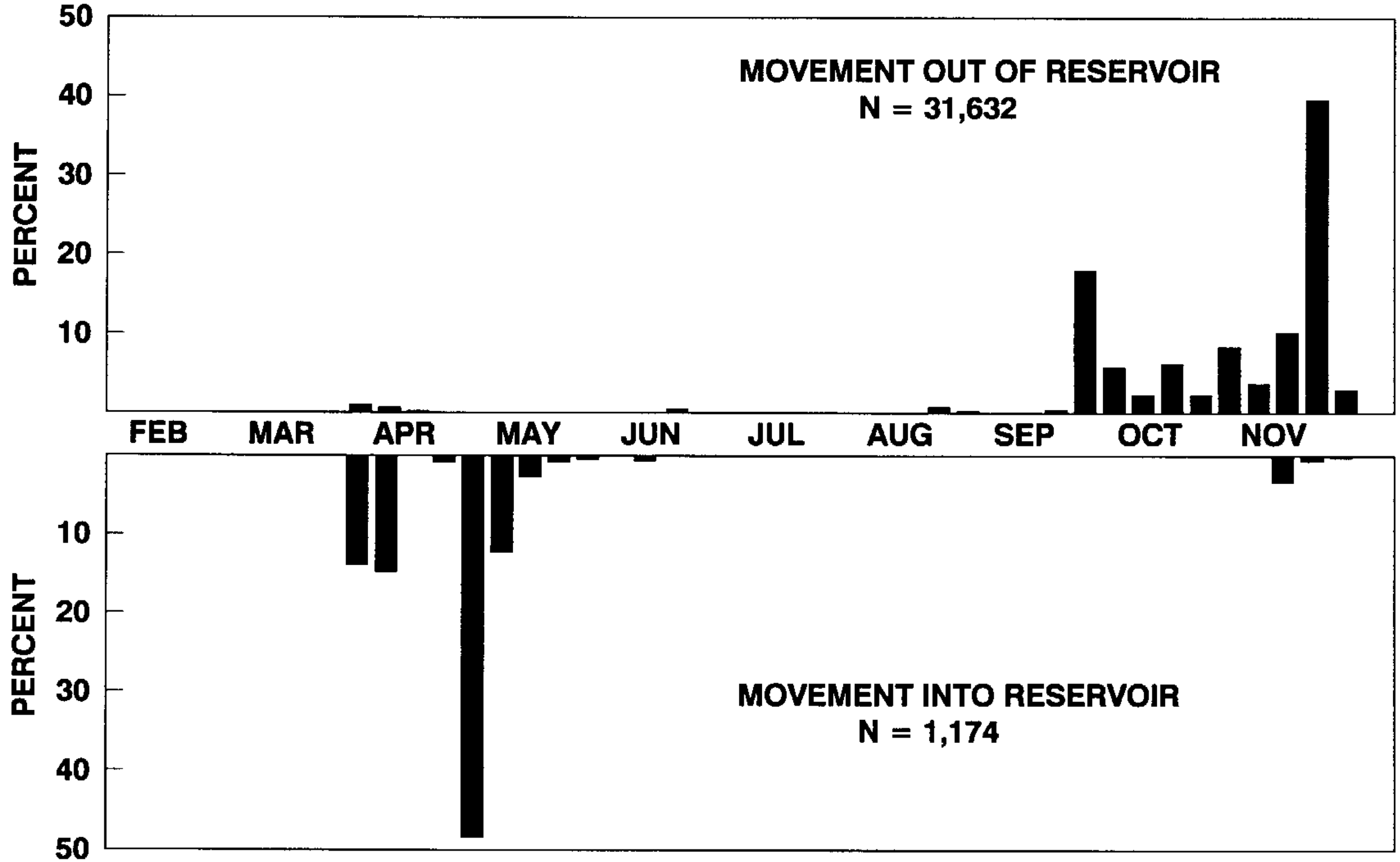

Figure 17. Weekly percentages of coho subyearlings moving into and out of Howard Hanson Reservoir based on mainstem fyke catches and hydroacoustic/scoop trap estimates. Mid-months are shown.

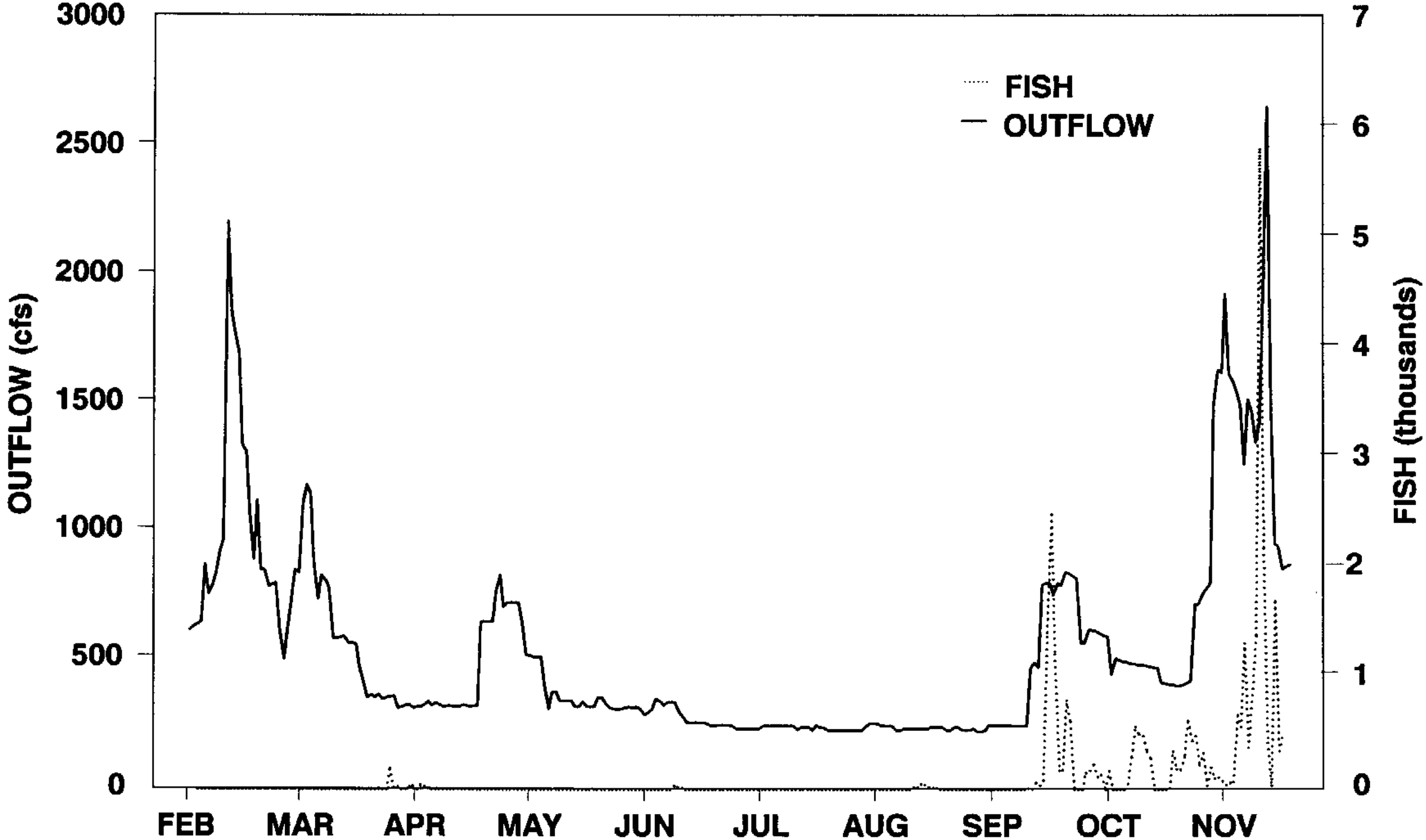

Figure 18. Subyearling coho passage and ouflow at Howard Hanson Dam. Mid-months are shown.

Table 1. Estimates of fish passage through Howard Hanson Dam by periods of gate operation.

Period	Estimated fish passage					Total	(%)
	Chin (1+)	Chin (0+)	Coho (1+)	Coho (0+)	Sthd (2+)		
Feb 18-Apr 8 (radial gate 1)	37	37,268	2,105	0	27	39,437	(18)
Apr 9-Apr 30 (bypass)	40	2,692	42	402	0	3,176	(1)
May 1-May 13 (bypass and radial gate 1)	1	4,219	2,175	0	0	6,395	(3)
May 14-Sept 25 (bypass)	1,567	84,867	2,496	304	5	89,239	(40)
Sept 26-Sept 28 (bypass and radial gate 2)	0	313	0	192	0	505	(<1)
Sept 29-Nov 9 (radial gate 2)	0	27,426	237	13,693	0	41,356	(19)
Nov 10-Nov 30 (radial gates 1 and 2)	0	22,211	434	17,041	0	39,686	(18)
Total	1,645	178,996	7,489	31,632	32	219,794	(100)

Table 2. Juvenile chinook collected for age analysis. Scale analysis indicated all fish were subyearlings (age 0+).

Collection date	Collection location	Mean length (mm)	s.d.	n
February 28	Scoop trap	46.1	2.0	10
March 13	North Fork trap	45.4	1.9	10
March 27	Scoop Trap	59.2	4.6	10
March 27	Mainstem Trap	53.0	6.3	9
March 27	North Fork Trap	50.3	2.0	10
April 10	Scoop Trap	65.0	3.0	10
April 10	Mainstem Trap	61.8	3.8	10
April 28	Mainstem Trap	66.9	2.9	9
May 22	Mainstem Trap	76.6	4.1	7
May 22	Scoop Trap	94.1	3.8	10
May 27	Forebay	108.4	6.2	31
May 29	Forebay	107.8	6.5	33
June 2	Forebay	107.6	4.8	32
June 5	Forebay	108.1	4.0	17
June 9	Scoop Trap	109.2	4.4	10
June 22	Scoop Trap	153.3	3.0	4
June 23	Scoop Trap	115.4	5.1	10
July 7	Scoop Trap	127.3	7.3	10
July 21	Scoop Trap	137.2	7.4	10
August 6	Forebay	147.2	5.6	9
August 10	Scoop Trap	135.0	-	1
August 19	Forebay	154.0	9.7	10
September 1	Forebay	158.1	5.9	8
September 16	Forebay	167.8	6.1	10
September 23	Scoop Trap	161.1	10.9	10
October 6	Scoop Trap	172.1	8.2	10
October 22	Scoop Trap	175.4	9.8	10
November 6	Scoop Trap	166.4	8.9	10

Table 3. Percentages of injuries and mortalities in scoop trap catches during the 1992 study.

		Percentage of sample					
Species/year class	Sample size[A]	Mortality	Partially descaled[B]	Descaled[C]	Bruising	Eye injury	Multiple injuries[D]
Radial gate 1 (February 18 to April 8)							
Chinook (1+)	1	0	100	0	0	0	0
Chinook(0+)	408	11	7	2	1	4	2
Coho (1+)	39	0	8	0	0	0	0
Coho (0+)	0	-	-	-	-	-	-
Bypass (April 9 to April 30)							
Chinook (1+)	2	0	0	0	0	0	0
Chinook (0+)	72	1	7	0	1	3	1
Coho (1+)	5	0	0	0	0	20	0
Coho (0+)	17	0	0	0	0	0	0
Bypass and radial gate 1 (May 1 to May 13)							
Chinook (1+)	1	0	100	0	0	100	100
Chinook (0+)	17	0	0	0	0	0	0
Coho (1+)	0	-	-	-	-	-	-
Coho (0+)	0	-	-	-	-	-	-
Bypass (May 14 to September 25)							
Chinook (1+)	55	15	18	18	4	4	16
Chinook (0+)	1,371	37	16	1	1	1	4
Coho (1+)	12	25	25	8	8	-	8
Coho (0+)	7	14	29	14	-	29	43

Table 3. Continued.

Species/year class	Sample size[A]	Percentage of sample					
		Mortality	Partially descaled[B]	Descaled[C]	Bruising	Eye injury	Multiple injuries[D]
Bypass and radial gate 2 (September 26 to September 28)							
Chinook (1+)	0	-	-	-	-	-	-
Chinook(0+)	43	86	2	12	0	0	7
Coho (1+)	14	42	14	0	0	0	0
Coho (0+)	0	-	-	-	-	-	-
Radial gate 2 (September 29 to November 9)							
Chinook (1+)	0	-	-	-	-	-	-
Chinook (0+)	376	42	22	8	2	7	17
Coho (1+)	3	0	0	0	0	33	0
Coho (0+)	95	1	12	1	3	11	4
Radial gate 1 and 2 (November 10 to November 30)							
Chinook (1+)	0	-	-	-	-	-	-
Chinook (0+)	488	35	39	37	2	1	22
Coho (1+)	33	3	36	6	0	3	3
Coho (0+)	323	6	39	7	1	3	7

Table 3. Continued.

Species/year class	Sample size[A]	Percentage of sample					
		Mortality	Partially descaled[B]	Descaled[C]	Bruising	Eye injury	Multiple injuries[D]
Entire study period (February 18 to November 30)							
Chinook (1+)	59	14	20	17	3	5	17
Chinook (0+)	2,775	33	19	8	1	2	9
Coho (1+)	104	10	18	5	1	2	2
Coho (0+)	444	5	32	6	2	5	4

Table 3. Continued.

[A] Fish examined for any injury during the time period shown. In large scoop trap catches, a random sample of fish (at lease 20 individuals of each species/year class) was examined

[B] From 3% to 16% scale loss on either side of fish in either a patchy or scattered pattern.

[C] Over 16% scale loss on either side of fish.

[D] Two or more of any injury categories, including mortality.

Table 4. Mean ATPase values and lengths from subyearling chinook salmon collected at various locations in the Howard Hanson project area.

Location	Date	ATPase		Length		Sample size
		Mean	S.D.	Mean	S.D.	
Scoop trap	Feb 28	6.6	3.0	46	2.1	9
Scoop trap	Mar 27	8.3	3.8	59	4.6	9
Scoop trap	Apr 10	11.4	4.2	65	3.0	10
Scoop trap	May 8	19.8	3.9	73	6.9	9
Scoop trap	May 22	29.3	5.7	94	3.8	10
Scoop trap	Jun 9	37.5	8.9	110	3.9	10
Scoop trap	Jun 23	55.9	10.6	115	5.1	10
Scoop trap	Jul 7	43.3	10.8	127	7.3	10
Scoop trap	Jul 21	43.2	13.8	137	7.4	10
Scoop trap	Sep 23	17.4	5.8	158	8.0	9
Scoop trap	Oct 6	20.9	7.9	172	8.2	10
Scoop trap	Oct 22	15.8	3.7	175	9.8	10
Scoop trap	Nov 6	14.0	5.6	166	8.9	10
Mainstem fyke	Mar 27	7.5	3.5	51	4.2	8
Mainstem fyke	Apr 10	9.1	3.4	62	3.8	10
Mainstem fyke	Apr 28	9.7	2.5	67	2.9	9
Mainstem fyke	May 22	18.3	4.7	77	4.1	7
North Fork	Mar 13	8.2	4.1	46	1.6	9
North Fork	Mar 27	6.6	1.3	50	2.1	9
Forebay	May 29	43.8	7.7	105	3.2	10
Forebay	Aug 6	28.9	9.5	147	5.6	9
Forebay	Aug 19	36.3	7.4	154	9.7	10
Forebay	Sep 1	28.0	11.4	158	6.0	8
Forebay	Sep 16	30.0	12.5	167	5.4	10

Table 5. Typical ATPase levels associated with juvenile chinook and coho salmon. Levels shown are general guidelines and not strict criteria. ATPase levels are expressed in μmoles ATP hydrolyzed per mg protein per hour.

ATPase level		
Chinook[A]	Coho[B]	Degree of smoltification
< 8	5-10	Baseline
9-11	12-30	Onset of smoltification
12-24	15-35	Smoltification progressing
> 24	30-50	Emigrating smolts

[A] Sources: Hosey and Associates (1990); Wunderlich and Dilley (1990).
[B] Source: Schroder and Fresh (1992).

Table 6. Biweekly mean forklengths of subyearling and yearling coho and chinook caught in the scoop trap in 1992.

Beginning date	Coho (0+)		Coho (1+)		Chinook (0+)		Chinook (1+)	
	Mean length (mm)	Sample size	Mean length (mm)	Sample size	Mean length (mm)	Sample size	Mean length (mm)	Sample size
Feb 18	-	-	94	15	46	69	-	-
Mar 1	-	-	97	4	48	38	-	-
Mar 15	-	-	99	10	60	78	-	-
Mar 29	-	-	99	12	61	244	-	-
Apr 12	48	7	107	2	66	35	130	2
Apr 26	-	-	-	-	74	12	-	-
May 10	-	-	117	3	93	101	160	3
May 24	-	-	-	-	102	137	143	2
Jun 7	-	-	-	-	114	307	150	20
Jun 21	96	1	137	3	128	402	163	17
Jul 5	-	-	-	-	130	52	163	2
Jul 19	-	-	137	7	138	20	166	1
Aug 2	-	-	137	3	137	10	-	-
Aug 16	100	1	-	-	150	2	-	-
Aug 30	-	-	-	-	-	-	-	-
Sep 13	122	9	-	-	163	32	-	-
Sep 27	116	36	145	1	168	60	-	-
Oct 11	112	19	-	-	172	19	-	-
Oct 25	113	27	155	1	175	113	-	-
Nov 8	113	106	165	11	179	180	-	-
Nov 22	119	115	163	14	181	83	-	-

Table 7. Mean ATPase values and lengths from juvenile coho salmon collected at various locations in the Howard Hanson project area.

Location	Date	ATPase		Length		Sample size
		Mean	S.D.	Mean	S.D.	
		Yearlings				
Mainstem fyke	Apr 28	13.4	3.5	105	8.4	8
Scoop trap	Apr 10	12.7	4.3	95	3.0	4
Scoop trap	Sep 23	6.6	-	131	-	1
		Subyearlings				
North Fork	Jun 12	6.3	1.5	50	3.8	10
Scoop trap	Sep 29	4.8	1.1	121	8.4	10
Scoop trap	Nov 17	5.3	0.8	127	23.3	9

Table 8. Summary of correlations between fish passage at Howard Hanson Dam in 1991 and 1992, and exit flow and depth (by period). Dates of 1991 periods are listed on page 9 of Dilley and Wunderlich (1992); dates of 1992 periods are listed on pages 9-10 of this report. Except as noted, increased fish passage was related to increased exit outflow. Where no value is shown, no relation was detected.

Passage of	Year	Correlation (r^2)					
		Pre-refill	Test refill	Refill	High pool	Total draw-down	Final draw-down
Chinook yearling	1991						
	1992						
Chinook subyear-ling	1991				0.53	0.34	0.19
	1992			0.19			0.13
Coho yearling	1991		0.95	0.97[A]			
	1992						
Coho subyear-ling	1991						0.27
	1992			0.22[B]		0.37	

[A] Reduced coho yearling passage was related to both reduced exit outflow and increased exit depth.
[B] Reduced coho subyearling passage was related to increased exit depth (outflow was not related).

Appendix A. Subyearling anadromous salmonids planted above Howard Hanson Dam in recent years. Sources of data: Washington Departments of Fisheries and Wildlife, and Muckleshoot Indian Tribe.

Year	Release date(s)	Size (number/pound)	Number released[A]
	Steelhead		
1989	Aug 24	330	46,530
1990	Aug 30	162	32,562
	Chinook Salmon		
1990	Feb 14	472	622,686
	Feb 28-Mar 7	400-406	1,080,203
			1,702,889
1991	Feb 21-25	449	979,446
	Mar 6-7	515	960,084
			1,939,530
1992	Feb 18-20	484	569,565
	Mar 23-30	267	554,742
	Apr 1-2	177	112,217
			1,236,524
	Coho Salmon		
1990	Mar 12	670	249,240
	Apr 3	499	67,864
	Apr 9	448	195,594
	May 7	387	157,896
	May 8	366	306,342
	May 9	379	270,606
	May 10	380	87,400
			1,334,942
1991	Apr 17-19	533	1,028,157
1992	Apr 6-7	464	458,316
	Apr 30	331	149,114
	May 1-5	331	325,792
			933,222

[A] Annual totals are highlighted.

Appendix B. Scoop trap catches below Howard Hanson Dam in 1992.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
FEB 19	0	0	0	0	0
FEB 21	2	0	0	7	0
FEB 25	8	0	1	6	0
FEB 27	3	0	0	23	0
FEB 28	2	0	0	35	0
MAR 2	0	0	0	15	0
MAR 3	2	0	0	35	0
MAR 5	0	0	0	0	0
MAR 6	0	0	0	0	0
MAR 9	0	0	0	0	0
MAR 10	1	0	0	0	0
MAR 12	0	0	0	0	0
MAR 13	1	0	0	0	0
MAR 16	0	0	0	0	0
MAR 17	1	0	0	0	0
MAR 19	0	0	0	0	0
MAR 20	1	0	0	0	0
MAR 23	0	0	0	0	0
MAR 24	0	0	0	3	0
MAR 26	5	0	0	90	1
MAR 27	2	0	0	271	1
MAR 28	1	0	0	658	0
MAR 30	0	0	0	183	0
MAR 31	3	0	0	275	0
APR 2	3	0	0	593	0
APR 3	0	0	0	284	0
APR 6	0	0	0	107	0
APR 7	2	0	0	155	1
APR 9	0	2	0	14	0
APR 10	4	7	0	76	0
APR 13	0	0	0	0	0
APR 14	0	5	0	10	0
APR 16	1	0	0	6	0
APR 17	0	2	0	19	0
APR 20	0	0	2	0	0
APR 21	1	0	0	2	0
APR 23	0	0	0	0	0
APR 24	0	0	0	0	0
APR 27	0	0	0	0	0
APR 28	0	0	0	0	0
APR 30	0	0	0	0	0
MAY 1	0	0	0	0	0
MAY 4	0	0	0	2	0
MAY 5	0	0	0	1	0
MAY 7	0	0	0	0	0
MAY 8	0	0	0	9	0

Appendix B. Continued.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
MAY 11	0	0	0	0	0
MAY 12	0	0	1	5	0
MAY 14	0	0	0	6	0
MAY 15	0	0	0	1	0
MAY 18	1	0	0	2	0
MAY 19	1	0	1	47	0
MAY 20	1	0	0	0	0
MAY 21	0	0	1	40	0
MAY 22	0	0	0	0	0
MAY 25	0	0	0	0	0
MAY 26	0	0	1	5	0
MAY 27	0	0	0	55	0
MAY 28	0	0	0	11	0
MAY 29	0	0	0	13	0
JUN 1	0	0	0	18	0
JUN 2	0	0	0	11	0
JUN 4	0	0	0	20	1
JUN 5	0	0	1	29	0
JUN 8	0	0	0	41	0
JUN 9	0	0	0	74	0
JUN 11	0	0	5	44	0
JUN 12	0	0	2	58	0
JUN 15	0	0	0	24	0
JUN 16	0	0	0	7	0
JUN 18	0	0	11	107	0
JUN 19	0	0	2	198	0
JUN 22	0	0	8	318	0
JUN 23	0	1	1	336	0
JUN 25	1	0	4	433	0
JUN 26	0	0	1	189	0
JUN 29	2	0	3	156	0
JUN 30	0	0	0	104	0
JUL 6	0	0	2	31	0
JUL 7	0	0	0	19	0
JUL 13	0	0	0	2	0
JUL 14	0	0	0	0	0
JUL 20	0	0	0	13	0
JUL 21	0	0	0	0	0
JUL 27	5	0	1	6	0
JUL 28	2	0	0	1	0
AUG 3	2	0	0	7	0
AUG 4	0	0	0	1	0
AUG 10	1	0	0	1	0
AUG 11	0	0	0	1	0
AUG 17	0	0	0	1	0
AUG 18	0	0	0	1	0

Appendix B. Continued.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
AUG 24	0	0	0	0	0
AUG 25	0	1	0	0	0
AUG 31	0	0	0	0	0
SEP 1	0	0	0	0	0
SEP 8	0	0	0	0	0
SEP 9	0	0	0	0	0
SEP 14	0	0	0	0	0
SEP 15	0	0	0	0	0
SEP 22	0	0	0	1	0
SEP 23	1	1	0	19	0
SEP 25	0	0	0	0	0
SEP 26	0	66	0	108	0
SEP 28	0	0	0	0	0
SEP 29	0	49	0	18	0
OCT 5	0	0	0	0	0
OCT 6	1	1	0	49	0
OCT 8	0	0	0	0	0
OCT 9	0	4	0	14	0
OCT 13	0	0	0	0	0
OCT 14	0	0	0	3	0
OCT 15	0	1	0	0	0
OCT 16	0	0	0	14	0
OCT 19	0	0	0	0	0
OCT 20	0	3	0	2	0
OCT 21	0	6	0	0	0
OCT 22	0	9	0	0	0
OCT 23	0	0	0	0	0
OCT 26	0	0	0	0	0
OCT 27	0	0	0	4	0
OCT 29	0	0	0	0	0
OCT 30	1	3	0	12	0
NOV 2	0	0	0	0	0
NOV 3	0	11	0	53	0
NOV 5	0	0	0	0	0
NOV 6	0	13	0	106	0
NOV 9	0	52	0	371	0
NOV 10	0	0	0	0	0
NOV 12	3	26	0	394	0
NOV 13	0	0	0	0	0
NOV 16	0	0	0	0	0
NOV 17	3	34	0	120	0
NOV 19	0	0	0	0	0
NOV 20	5	160	0	343	0
NOV 23	0	0	0	143	0

Appendix B. Continued.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
NOV 24	8	1288	0	175	0
NOV 30	6	29	0	0	0

Appendix C. Mainstem Green River fyke trap catches.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
FEB 19	0	0	0	0	0
FEB 21	0	0	0	1248	0
FEB 25	6	0	0	178	0
FEB 28	2	0	0	30	0
MAR 3	2	0	0	35	0
MAR 6	1	0	0	6	0
MAR 10	0	0	0	0	0
MAR 13	2	0	0	3	0
MAR 17	2	0	0	0	0
MAR 20	1	0	0	0	0
MAR 24	0	0	0	7	0
MAR 28	2	0	0	1458	0
MAR 31	0	0	0	849	0
APR 3	0	0	0	202	0
APR 7	0	0	0	12	1
APR 10	0	79	0	45	0
APR 14	2	123	0	54	0
APR 17	3	42	0	97	0
APR 21	2	2	0	53	0
APR 24	0	0	0	2	0
APR 28	13	6	0	25	0
MAY 1	22	4	1	44	0
MAY 5	9	250	0	24	0
MAY 8	4	241	0	26	0
MAY 12	14	181	0	210	0
MAY 15	1	1	0	5	0
MAY 19	0	0	0	0	0
MAY 22	0	33	0	13	0
MAY 26	0	0	0	0	0
MAY 28	0	2	0	1	0
JUN 2	0	6	0	0	0
JUN 5	0	0	0	0	0
JUN 9	0	1	0	0	0
JUN 12	0	0	0	0	0
JUN 16	0	7	0	0	0
JUN 19	0	1	0	0	0
JUN 23	0	0	0	0	0
JUN 26	0	0	0	0	0
JUN 30	0	0	0	0	0
JUL 7	0	1	0	0	0
JUL 14	0	0	0	0	0
JUL 21	0	0	0	0	0
JUL 28	0	0	0	0	0
AUG 4	0	0	0	0	0
AUG 11	0	0	0	0	0
AUG 18	0	0	0	0	0

Appendix C. Continued.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
AUG 25	0	0	0	0	0
SEP 1	0	0	0	0	0
SEP 9	0	0	0	0	0
SEP 15	0	0	0	0	0
SEP 22	0	0	0	0	0
SEP 29	0	0	0	0	0
OCT 6	0	0	0	0	0
OCT 9	0	0	0	0	0
OCT 14	0	0	0	0	0
OCT 16	0	0	0	0	0
OCT 20	0	0	0	0	0
OCT 22	0	0	0	0	0
OCT 27	0	0	0	0	0
OCT 30	0	0	0	0	0
NOV 3	0	0	0	0	0
NOV 6	0	0	0	0	0
NOV 10	0	0	0	0	0
NOV 13	0	0	0	0	0
NOV 17	0	28	0	0	0
NOV 20	0	10	0	0	0
NOV 24	0	7	0	0	0
NOV 30	0	2	0	0	0

Appendix D. North Fork Green River fyke trap catches in 1992.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
FEB 19	1	0	0	0	0
FEB 21	0	0	0	342	0
FEB 25	0	0	0	16	0
FEB 28	1	0	0	0	0
MAR 3	0	0	0	0	0
MAR 6	0	0	0	0	0
MAR 10	0	0	0	0	0
MAR 13	0	0	0	1	0
MAR 17	0	0	0	0	0
MAR 20	0	0	0	0	0
MAR 24	0	0	0	0	0
MAR 28	0	0	0	1	0
MAR 31	0	0	0	0	0
APR 3	0	0	0	0	0
APR 7	0	0	0	0	1
APR 10	0	0	0	0	0
APR 14	0	0	0	0	0
APR 17	0	0	0	4	0
APR 21	2	0	0	0	0
APR 24	0	0	0	0	0
APR 28	0	0	0	0	0
MAY 1	0	0	0	2	0
MAY 5	0	0	0	0	0
MAY 8	0	0	0	0	0
MAY 12	0	0	0	0	0
MAY 15	0	0	0	0	0
MAY 19	0	0	0	0	0
MAY 22	0	0	0	0	0
MAY 26	0	0	0	0	0
MAY 28	0	0	0	0	0
JUN 2	0	0	0	0	0
JUN 5	0	0	0	0	0
OCT 6	0	0	0	0	0
OCT 9	0	0	0	0	0
OCT 14	0	0	0	0	0
OCT 16	0	0	0	0	0
OCT 20	0	0	0	0	0
OCT 22	0	0	0	0	0
OCT 27	0	0	0	0	0
OCT 30	0	0	0	0	0
NOV 3	0	0	0	0	0
NOV 6	0	0	0	0	0
NOV 10	0	3	0	0	0
NOV 13	0	0	0	0	0
NOV 17	0	0	0	0	0
NOV 20	0	0	0	0	0

Appendix D. Continued.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
NOV 24	0	1	0	0	0
NOV 30	0	0	0	0	0

Appendix E. Estimated daily fish passage at Howard Hanson Dam during the 1992 study.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
FEB 18	0	0	0	0	0
FEB 19	12	0	0	41	0
FEB 20	12	0	0	41	0
FEB 21	9	0	0	32	0
FEB 22	8	0	0	28	0
FEB 23	10	0	0	36	0
FEB 24	39	0	0	139	0
FEB 25	51	0	7	39	0
FEB 26	143	0	19	108	0
FEB 27	12	0	0	92	0
FEB 28	5	0	0	101	0
FEB 29	5	0	0	86	0
MAR 1	4	0	0	70	0
MAR 2	0	0	0	265	0
MAR 3	4	0	0	68	0
MAR 4	21	0	0	395	0
MAR 5	8	0	0	147	0
MAR 6	6	0	0	111	0
MAR 7	8	0	0	150	0
MAR 8	6	0	0	115	0
MAR 9	2	0	0	46	0
MAR 10	18	0	0	333	0
MAR 11	232	0	0	0	0
MAR 12	209	0	0	0	0
MAR 13	278	0	0	0	0
MAR 14	114	0	0	0	0
MAR 15	63	0	0	0	0
MAR 16	53	0	0	0	0
MAR 17	17	0	0	0	0
MAR 18	31	0	0	0	0
MAR 19	136	0	0	0	0
MAR 20	58	0	0	0	0
MAR 21	164	0	0	0	0
MAR 22	78	0	0	0	0
MAR 23	127	0	0	0	0
MAR 24	0	0	0	177	0
MAR 25	0	0	0	277	0
MAR 26	37	0	0	694	7
MAR 27	9	0	0	889	4
MAR 28	5	0	0	2389	0
MAR 29	1	0	0	462	0
MAR 30	0	0	0	1999	0
MAR 31	16	0	0	1548	0
APR 1	19	0	0	1864	0
APR 2	49	0	0	8173	0

Appendix E. Continued.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
APR 3	0	0	0	3218	0
APR 4	0	0	0	5354	0
APR 5	0	0	0	2923	0
APR 6	0	0	0	2163	0
APR 7	16	0	0	1546	16
APR 8	12	0	12	1148	0
APR 9	0	194	0	776	0
APR 10	13	21	0	230	0
APR 11	17	27	0	296	0
APR 12	3	4	0	45	0
APR 13	4	6	0	65	0
APR 14	0	29	0	60	0
APR 15	0	35	0	72	0
APR 16	6	0	0	120	0
APR 17	0	40	0	357	0
APR 18	0	31	0	281	0
APR 19	0	14	0	126	0
APR 20	0	0	40	0	0
APR 21	33	0	0	68	0
APR 22	26	0	0	52	0
APR 23	41	0	0	83	0
APR 24	13	0	0	25	0
APR 25	6	0	0	11	0
APR 26	0	0	0	0	0
APR 27	6	0	0	11	0
APR 28	2	0	0	4	0
APR 29	0	0	0	0	0
APR 30	4	0	0	9	0
MAY 1	668	0	0	1355	0
MAY 2	1361	0	0	2763	0
MAY 3	17	0	0	34	0
MAY 4	0	0	0	54	0
MAY 5	0	0	0	1	0
MAY 6	0	0	0	0	0
MAY 7	0	0	0	2	0
MAY 8	0	0	0	2	0
MAY 9	0	0	0	0	0
MAY 10	0	0	0	0	0
MAY 11	0	0	0	2	0
MAY 12	0	0	1	5	0
MAY 13	0	0	0	1	0
MAY 14	0	0	0	1	0
MAY 15	0	0	0	4	0
MAY 16	0	0	0	3	0
MAY 17	0	0	0	1	0
MAY 18	11	0	0	21	0

Appendix E. Continued.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
MAY 19	0	1	1	22	0
MAY 20	27	0	0	0	0
MAY 21	0	0	3	68	0
MAY 22	0	0	3	72	0
MAY 23	0	0	3	74	0
MAY 24	0	0	3	73	0
MAY 25	0	0	6	133	0
MAY 26	0	0	4	42	0
MAY 27	0	0	0	90	0
MAY 28	0	0	0	37	0
MAY 29	0	0	0	66	0
MAY 30	0	0	0	83	0
MAY 31	0	0	0	96	0
JUN 1	0	0	0	92	0
JUN 2	0	0	0	116	0
JUN 3	0	0	0	58	0
JUN 4	0	0	0	89	5
JUN 5	0	0	3	83	0
JUN 6	0	0	4	140	0
JUN 7	0	0	5	160	0
JUN 8	0	0	0	219	0
JUN 9	0	0	0	204	0
JUN 10	0	0	0	319	0
JUN 11	0	0	22	197	0
JUN 12	0	0	3	97	0
JUN 13	0	0	3	109	0
JUN 14	0	0	16	533	0
JUN 15	0	0	0	70	0
JUN 16	0	0	0	100	0
JUN 17	0	0	0	344	0
JUN 18	0	0	92	927	0
JUN 19	0	0	20	2001	0
JUN 20	0	0	67	6662	0
JUN 21	0	0	59	5881	0
JUN 22	0	0	221	5309	0
JUN 23	0	39	39	7742	0
JUN 24	0	28	28	5495	0
JUN 25	0	15	749	7399	0
JUN 26	0	0	34	6757	0
JUN 27	0	0	40	7969	0
JUN 28	0	0	8	1608	0
JUN 29	15	0	29	1416	0
JUN 30	0	0	0	3185	0
JUL 1	0	0	0	225	0
JUL 2	0	0	0	1282	0
JUL 3	0	0	0	2818	0

Appendix E. Continued.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
JUL 4	0	0	0	369	0
JUL 5	0	0	0	1247	0
JUL 6	0	0	18	287	0
JUL 7	0	0	0	158	0
JUL 8	0	0	0	131	0
JUL 9	0	0	0	862	0
JUL 10	0	0	0	336	0
JUL 11	0	0	0	217	0
JUL 12	0	0	0	221	0
JUL 13	0	0	0	133	0
JUL 14	0	0	0	222	0
JUL 15	0	0	0	133	0
JUL 16	0	0	0	158	0
JUL 17	0	0	0	349	0
JUL 18	0	0	0	686	0
JUL 19	0	0	0	357	0
JUL 20	0	0	0	181	0
JUL 21	0	0	0	58	0
JUL 22	0	0	0	37	0
JUL 23	0	0	0	75	0
JUL 24	0	0	0	184	0
JUL 25	0	0	0	1047	0
JUL 26	0	0	0	612	0
JUL 27	438	0	84	522	0
JUL 28	403	0	0	198	0
JUL 29	477	0	0	235	0
JUL 30	331	0	0	163	0
JUL 31	172	0	0	85	0
AUG 1	64	0	0	32	0
AUG 2	353	0	0	174	0
AUG 3	87	0	0	309	0
AUG 4	0	0	0	29	0
AUG 5	0	0	0	137	0
AUG 6	0	0	0	25	0
AUG 7	0	0	0	25	0
AUG 8	0	0	0	331	0
AUG 9	0	0	0	206	0
AUG 10	98	0	0	98	0
AUG 11	0	0	0	142	0
AUG 12	0	0	0	97	0
AUG 13	0	0	0	152	0
AUG 14	0	0	0	138	0
AUG 15	0	0	0	136	0
AUG 16	0	0	0	155	0
AUG 17	0	0	0	139	0
AUG 18	0	0	0	133	0

Appendix E. Continued.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
AUG 19	0	0	0	148	0
AUG 20	0	0	0	176	0
AUG 21	0	0	0	31	0
AUG 22	0	0	0	29	0
AUG 23	0	0	0	79	0
AUG 24	0	0	0	57	0
AUG 25	0	24	0	0	0
AUG 26	0	23	0	0	0
AUG 27	0	50	0	0	0
AUG 28	0	47	0	0	0
AUG 29	0	29	0	0	0
AUG 30	0	14	0	0	0
AUG 31	0	14	0	0	0
SEP 1	0	0	0	59	0
SEP 2	0	0	0	29	0
SEP 3	0	0	0	62	0
SEP 4	0	0	0	16	0
SEP 5	0	0	0	111	0
SEP 6	0	0	0	36	0
SEP 7	0	0	0	25	0
SEP 8	0	0	0	9	0
SEP 9	0	0	0	347	0
SEP 10	0	0	0	82	0
SEP 11	0	0	0	59	0
SEP 12	0	0	0	53	0
SEP 13	0	0	0	166	0
SEP 14	0	0	0	23	0
SEP 15	0	0	0	29	0
SEP 16	0	0	0	58	0
SEP 17	0	0	0	74	0
SEP 18	0	0	0	108	0
SEP 19	0	0	0	60	0
SEP 20	0	0	0	9	0
SEP 21	0	0	0	132	0
SEP 22	0	0	0	218	0
SEP 23	1	1	0	14	0
SEP 24	12	12	0	216	0
SEP 25	8	8	0	141	0
SEP 26	0	67	0	110	0
SEP 27	0	40	0	65	0
SEP 28	0	85	0	138	0
SEP 29	0	1429	0	529	0
SEP 30	0	2505	0	926	0
OCT 1	0	1230	0	455	0
OCT 2	0	174	0	64	0
OCT 3	0	177	0	66	0

Appendix E. Continued.

DATE	COHO 1+	COHO 0+	CHINOOK 1+	CHINOOK 0+	STEELHEAD
OCT 4	0	810	0	299	0
OCT 5	0	620	0	229	0
OCT 6	7	0	0	343	0
OCT 7	6	0	0	285	0
OCT 8	5	0	0	227	0
OCT 9	0	156	0	623	0
OCT 10	0	174	0	698	0
OCT 11	0	232	0	928	0
OCT 12	0	118	0	471	0
OCT 13	0	138	0	551	0
OCT 14	0	0	0	297	0
OCT 15	0	172	0	0	0
OCT 16	0	0	0	401	0
OCT 17	0	0	0	379	0
OCT 18	0	0	0	232	0
OCT 19	0	0	0	383	0
OCT 20	0	59	0	40	0
OCT 21	0	305	0	0	0
OCT 22	0	571	0	0	0
OCT 23	0	502	0	0	0
OCT 24	0	490	0	0	0
OCT 25	0	350	0	0	0
OCT 26	0	288	0	0	0
OCT 27	0	0	0	146	0
OCT 28	0	0	0	103	0
OCT 29	0	0	0	120	0
OCT 30	3	8	0	32	0
OCT 31	7	19	0	80	0
NOV 1	135	346	0	1442	0
NOV 2	74	192	0	798	0
NOV 3	0	189	0	921	0
NOV 4	0	319	0	1557	0
NOV 5	0	624	0	3049	0
NOV 6	0	447	0	3616	0
NOV 7	0	490	0	3961	0
NOV 8	0	228	0	1846	0
NOV 9	0	332	0	1327	0
NOV 10	0	41	0	165	0
NOV 11	0	208	0	833	0
NOV 12	17	104	0	1611	0
NOV 13	19	114	0	1770	0
NOV 14	14	81	0	1257	0
NOV 15	8	48	0	744	0
NOV 16	12	69	0	1071	0
NOV 17	7	77	0	268	0
NOV 18	62	677	0	2338	0

Appendix E. Continued.

DATE	COHO		CHINOOK		STEELHEAD
	1+	0+	1+	0+	
NOV 19	52	572	0	1976	0
NOV 20	43	1332	0	2921	0
NOV 21	12	387	0	848	0
NOV 22	28	859	0	1885	0
NOV 23	46	1412	0	3097	0
NOV 24	7	5822	0	787	0
NOV 25	2	2193	0	297	0
NOV 26	0	429	0	58	0
NOV 27	0	42	0	6	0
NOV 28	2	1713	0	232	0
NOV 29	0	354	0	48	0
NOV 30	104	506	0	0	0